THE MANUFACTURE OF CANE SUGAR

BY

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SECOND EDITION, REVISED, WITH 270 ILLUSTRATIONS AND DIAGRAMS

WITH AN INTRODUCTION BY

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PUBLISHED UNDER THE AUSPICES OF
THE WEST INDIA COMMITTEE

BY

DUCKWORTH & CO.

3, HENRIETTA STREET, COVENT GARDEN, LONDON

PREFACE

This work on the manufacture of cane sugar, which the authors now present to the public, is not primarily intended to be a scientific exposition of the subject, but, rather, a guide for the use of those who are connected, directly or indirectly, with the cane sugar industry otherwise than in a technical capacity. It is also intended to supply a record of the position of cane sugar manufacture at the present day.

The authors desire to express their thanks to the following engineering firms who so generously helped them by providing drawings, photographs and blocks for many of the illustrations which appear in the following pages, notably Aitken and Co.; Babcock and Wilcox, Ltd.; Bellingham and Stanley, Ltd.; Blair, Campbell and McLean, Ltd.; Clarke Chapman and Co., Ltd.; Fawcett, Preston and Co., Ltd.; George Fletcher and Co., Ltd.; E. Green and Son, Ltd.; The Harvey Engineering Co., Ltd.; The Kestner Evaporator and Engineering Co., Ltd.; Manlove, Alliott and Co.; John McNeil and Co., Ltd.; The Mirrlees Watson Co., Ltd.; Pott, Cassels and Williamson; A. and W. Smith and Co., Ltd.; Duncan Stewart and Co., Ltd.; The Stirling Boiler Co., Ltd.; and Watson, Laidlaw and Co., Ltd. They also wish to thank Mr. Algernon Aspinall, C.M.G., Secretary of The West India Committee, for the great trouble which he has taken in editing the book.

L. J.
F. I. S.

INTRODUCTION TO SECOND EDITION

When "The Manufacture of Cane Sugar" was first published, it was immediately accepted as a standard work on the subject with which it deals. The first impression was quickly sold, and since it has been out of print there has been an insistent demand for the publication of a second. Though the authors might have arranged for a reprint to be issued, they preferred to wait until they were in a position to publish a new and revised edition embodying particulars of the latest improvements and developments in the cane sugar world. For a time this was not practicable, owing to the prolonged absence of one of the authors in a progressive cane sugar producing country and to circumstances arising out of the war. This unavoidable delay has, however, been in one way advantageous, inasmuch as it has enabled Mr. Llewellyn Jones and Mr. F. I. Scard to include in this new edition of the work, which has been most carefully revised and rewritten where necessary, illustrations and descriptions of recent apparatus and processes of manufacture that have contributed towards bringing about the present commercial supremacy of cane sugar over beet. In an introduction to the first edition, the late Sir Nevile Lubbock, K.C.M.G., called attention to the fact that, since the abolition of the foreign bounties and the suppression of cartels by the International Agreement embodied in the Brussels Sugar Convention of 1902, the cane sugar industry had rapidly overtaken that of beet. Leaving out of the question India's 2,000,000 tons of cane sugar which

was consumed locally, he showed in this connection that whereas in 1901 the production of beet exceeded that of cane (the actual figures being: beet sugar, 6,237,903 tons, and cane sugar, 6,197,187 tons), in 1909 cane sugar had once again taken the lead, the comparative figures for 1908–9 being: cane sugar, 7,562,740 tons, and beet, 6,898,010 tons.

During the Great War the position of the cane industry was further strengthened, the world's production of cane sugar (including that of India) rising to 12,412,456 tons in 1917–18, whilst that of beet fell to 5,010,133 tons, the European production being 4,316,016 tons only in the same year, and falling to 2,603,480 tons in 1919-20. The Continental beet industry is now, however, showing rapid recovery, the latest estimate for the 1921–22 crop being 3,895,000 tons, as compared with 2,618,000 tons for 1919–20. It is clear, therefore, that the competition between cane sugar and beet will be renewed in the near future—possibly in an acute form unless the world's exchanges are stabilised. From this it follows that it behoves producers of cane sugar to continue to strain every nerve to retain their supremacy by the adoption of the most modern machinery and processes of manufacture, and by the scientific control of their factories. It is here that they will find "The Manufacture of Cane Sugar" particularly useful. The day has gone when estates proprietors could afford to depend on their managers and head overseers alone knowing what was moving in the cane sugar world. They must possess such knowledge themselves, and it must also be imparted to the field and factory staffs if success is to be assured. No more suitable means of imparting it could be found than by this book.

ALGERNON ASPINALL.

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THE MANUFACTURE OF CANE SUGAR

CHAPTER I

THE SUGAR-CANE

THE sugar-cane, *Saccharum officinarum*, which belongs to the natural order *Gramineæ*, grows in all tropical and sub-tropical countries, and although it attains its best development in lower levels, it is stated to be capable of cultivation up to elevations of 6000 feet. A hot, moist climate, with a dry ripening season, shows the sugar-cane at its best, any lowering of the temperature at once affecting its growth prejudicially. The East is generally believed to have been its original home, and its presence in the West is usually attributed to the Spaniards, who had already received it from the Moors. Old writers, however, assert that the sugar-cane is indigenous to the West Indies and Central America. At any rate, the introduction of the art of sugar-making into Cuba and Mexico may be credited to the Spaniards.

A sugar-cane consists of root, stalk, flower, and leaves. The roots, which ramify from the base of the stem, extend to variable distances—18 inches to 3 feet—on all sides, the distance depending mainly upon the condition of the soil. If the latter permits, cane roots will penetrate to a considerable extent, especially in search of water. The stalk consists of joints, which vary in size and number, 5 to 6 inches being a fair average length. Immediately above each

Fig. 1.—Stool of sugar-cane ready for cutting, showing "trashed" stem, "tops," and "arrow."

node or joint division a contracted ring is invariably found. The stalk of a cane may run up to 20 feet, but 8 to 12 feet

is a fair length. The main bulk of a cane is made up of soft sugar-containing cells, amongst which run lengthwise the fibrous strands, or fibro-vascular bundles. Figs. 2 and 3, illustrating canes cut transversely, show the arrangement of these bundles; all the intervening portions represent the sugar-containing tissue. The fibro-vascular bundles are the channels along which water and plant food from the roots reach the leaves, and the sugar and other products

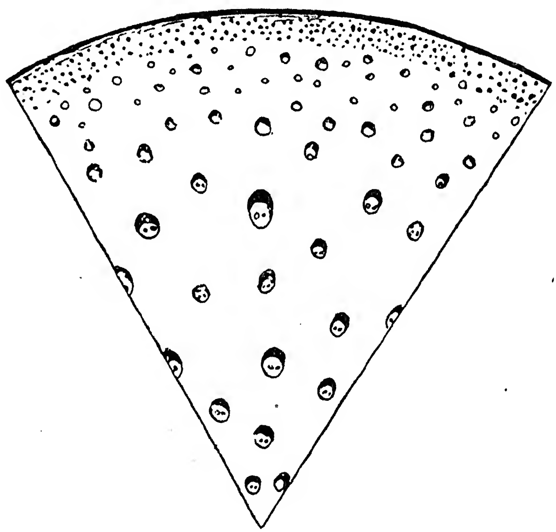


FIG. 2.—Transverse section of sugar-cane, showing the scattered bundles. The intervening portion is made up of the sugar-containing cells.

elaborated there pass down into the stem. The principal conducting tubes or vessels are shown by the large circular openings in the bundle cut across and figured, highly magnified, in Fig. 3. The surface of the rind is coated to a greater or less extent with a species of wax, the degree to which this occurs forming an important feature in cane classification. In the contraction just above each node are small spots from which roots develop during the germination of the bud. Nestling in the sheath of the leaf at each joint

a bud appears, which forms the basis of future canes. One leaf springs from each joint, the base forming a sheath around the joint. The bloom, or arrow, which bursts from a sheath shooting up from the apex of the cane at the time of flowering, consists of large white or grey compound clusters, made up of countless small silky flowers.

The sugar-cane is invariably propagated in agriculture by cuttings. The flowers, or arrows, contain seeds, but from the system of reproduction employed they have become

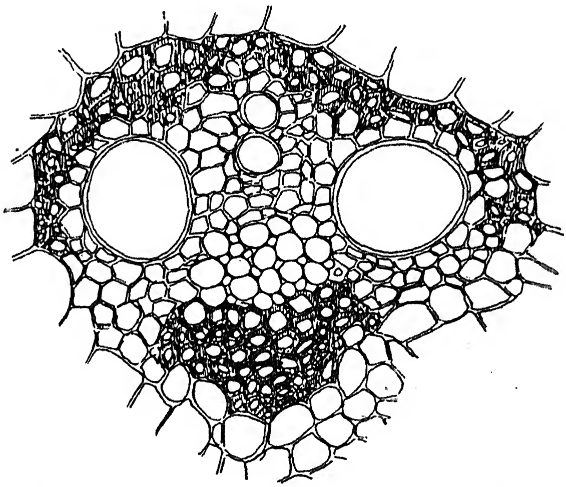


FIG. 3.—A single fibro-vascular bundle of sugar-cane, showing the large vessels or tubes surrounded by woody fibre (highly magnified).

to a greater or less extent sterile. Apart from this, the tendency to atavism, or harking back to previous types, renders growth from such seed out of the question for estates' purposes, although the rediscovered property of propagation by seed is being largely used for the development of new varieties. While cuttings, then, are invariably used for planting purposes, some difference in practice occurs as to what portion of the cane is used. In most countries the top, or upper joints of the cane, after the

head has been removed, is exclusively used, but frequently the whole cane is utilised, being cut up into sections long

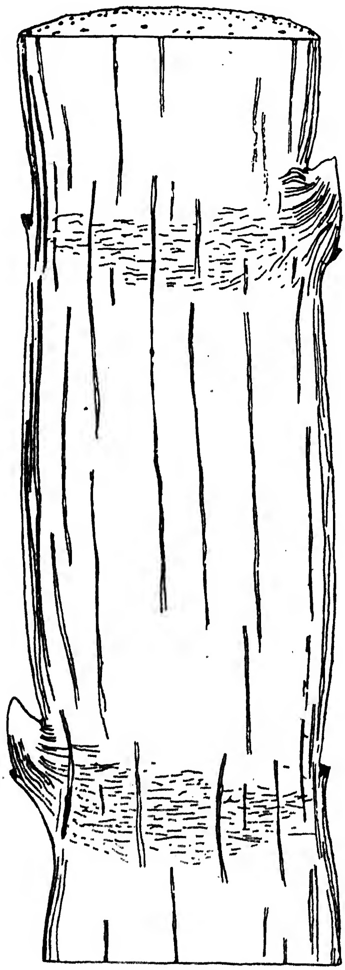


FIG. 4.—Longitudinal section of sugar-cane, showing course of fibro-vascular bundles.

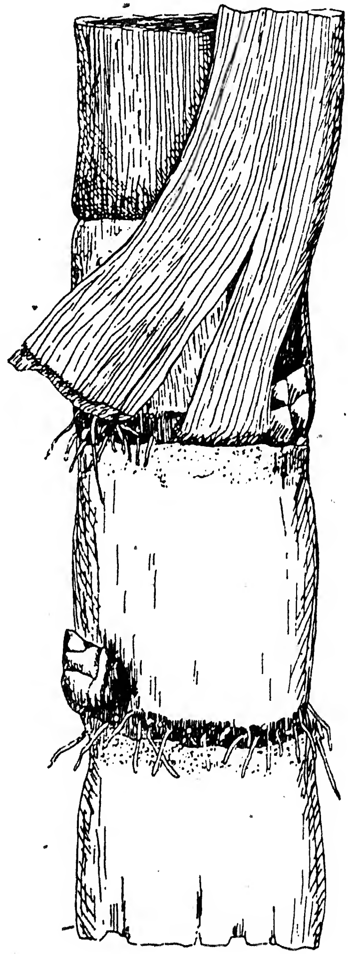


FIG. 5.—Beginning of germination of a sugar-cane top, showing nodes, internodes or joints, buds and sheath of leaf, with rudimentary roots.

enough to provide two or three joints for each. As mentioned above, each joint contains a bud, the germina-

tion of which gives rise to the new cane; but as these are in the best condition for development in the upper or softer parts of the cane, tops are generally considered most suitable for planting. As, however, the use of them necessitates either the sacrifice of the rest of the cane or its manufacture into sugar, for which the planting season

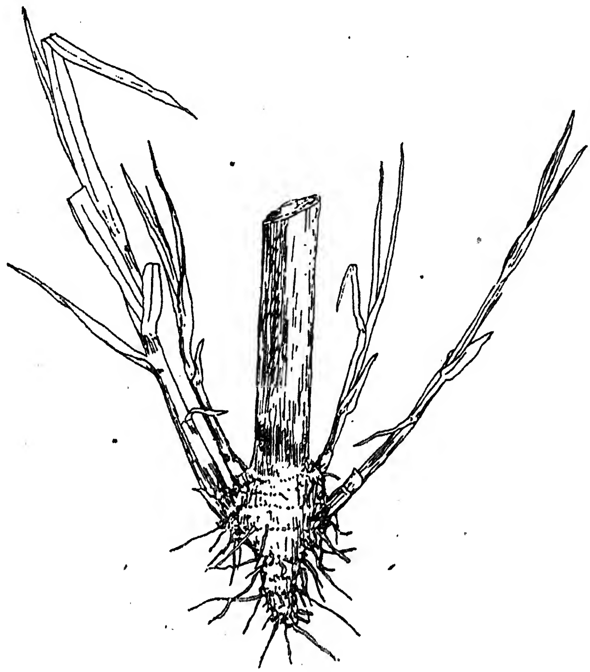


FIG. 6.—Germinating sugar-cane "top," showing young shoots developed from the buds or "eyes," and the young roots.

may not be suitable, the whole length of the stalk is used for plants in many instances. In either method the "eyes," under suitable conditions, spring, a number of roots being thrown out from and around the joint, which serve to supply the young canes with means of subsistence until they can put forth roots of their own. Planting is done either in furrows or in holes. In the former case, the

"top" is either thrust into the soil at angles varying according to the local practice or else laid horizontally and lightly buried. The rows thus formed are from 3 to 6 feet apart, and the plants are placed at short intervals, from 1 to 2 feet along them. When holes are dug—they vary in distance according to the soil conditions—the plants are either laid horizontally and covered, or else inserted in the soil as above. The sugar-cane requires a considerable quantity of water for its growth, but at the same time good drainage; and in those countries where there is a deficient rain supply, but where the soil and drainage conditions suit, irrigation is practised with great success. In fact, it is with a good open soil, constant high temperature, and control of the water supply, that cane cultivation is carried on under the most favourable conditions.

Although the details of cultivation vary considerably in cane-producing countries, the main features are the same. The soil is prepared for planting by ploughing, either by steam ploughs, by ploughs drawn by mules or oxen, or by hand-forking. The canes are planted, and when of sufficient age—that is to say, when from one to three months old—are manured. Where farmyard manure is employed this is ploughed in before planting. The canes as they grow are "moulded" from the surrounding soil, so as to keep the root well below the surface, and the necessary weeding and tillage done. After six or seven months the cane stool covers the ground sufficiently to render further operations unnecessary, and it is left to complete its growth and to mature. As the cane approaches maturity the trash or dead leafage of the earlier growth is removed. The usual period of maturity is sixteen months in the case of plant canes and twelve months in that of ratoons, but in countries, such as Louisiana, where a cold

season exists, the period available for growth is not more than eight or nine months. At the flowering season various changes take place in the juice. The proportion of uncrystallisable sugar is much increased, and so too is that of the organic impurities. As the arrow, or flower, drops, however, this gradually diminishes, together with the albuminous and gummy matters of the juice, while the purity of the juice, *i.e.* the relation of the quantity of cane sugar to the other solids of the juice, increases until the moment of maximum ripeness occurs. When this is past, the cane begins to dry up, and with the advent of rains growth appears in the "eyes" and from the roots. If allowed to remain longer the old cane withers, while small shoots appear as ramifications from its side. After the cane is cut, shoots appear if the "stool" is allowed to remain in the ground, and these form a new growth of cane. They are termed ratoons, and the extent to which a field of cane is "ratooned" depends entirely upon the soil and system of cultivation. In rich soils the operation can be repeated successfully for some years. In Java, however, only plant canes are grown, Government regulations until recently forbidding the cultivation of ratoons. Ratoon canes ripen earlier than plant canes, and, as a rule, have not the same luxuriance of growth.

The soils most suitable to the sugar-cane are clays and loams, which, while retaining moisture, remain open enough to permit of proper aeration and drainage. The sugar-cane makes but a small demand upon the constituents of the soil, less than a half per cent. of its weight being abstracted in the form of mineral matter. Potash, phosphoric acid, and nitrogen are the principal foods required, and lime, as with most crops, is an important adjunct. As regards the composition of good cane soils, those of Hawaii, which are especially fertile, contain about 3 per cent. of potash, from

·18 to ·51 per cent. of phosphoric acid, and from ·17 to ·54 per cent. of nitrogen. The alluvial cane lands of Louisiana contain from ·09 per cent. to ·75 per cent. of potash, from ·06 to ·146 per cent. of phosphoric acid, and from ·06 to ·130 per cent. of nitrogen. It is not, however, the proportion of the chemical constituents which determines the fertility of the soil so much as the quantity available for the immediate purposes of the plant, and the favourable condition of the soil for the development of bacterial life. When the soil is light and wanting in depth, farmyard manure or heavy green soiling is indispensable for the maintenance of the "body" of the soil. It is of the greatest importance also, especially with heavy clays, that the proportion of humus or vegetable matter of the soil should be maintained, and to this end the "trash," and as much of the debris of the canes as possible, should be returned to the soil. The refuse of the cane after crushing —the bagasse or megass—is used for fuel purposes, and the trash available is not itself sufficient (especially in face of a tropical rainfall, which washes away the lighter part of the soil) to make up for the loss of humus. "Green soiling" the growth of catch crops—crops grown between the cutting and replanting of the cane—or of rotation crops calculated to give a large amount of organic debris, is therefore practised where the system of cultivation permits. As regards artificial manures, what are generally required for manurial purposes are assimilable forms of nitrogen and of phosphoric acid and potash where the amounts of these available are wanting. It has been already mentioned that the sugar-cane requires good drainage, and to meet tropical conditions of rainfall the open drain system is almost invariably employed. In those countries, such as British Guiana and Louisiana, which are below the level of the sea or river, the drainage water has to be pumped

away from the estate, though sometimes the fall of the tide is utilised for this purpose.

The proportion of the constituents of the sugar-cane varies considerably, but the following may be taken as giving a rough idea of the general composition of the cane as cut:—

Water	from 69	to	75 per cent.	
Sucrose	,, 8	,,	16	,,
Uncrystallisable sugar	trace	,,	2	,,
Fibre	from 8	,,	16	,,
Ash	,, 0·3	,,	0·8	,,
Organic matter other than sugar	,, 0·5	,,	1	,,
Containing nitrogen	about 0·02	,,	0·05	,,

The composition of a particular cane varies considerably according to climate and soil. A description of cane which gives a rich juice under certain conditions would give a poor juice under others. The lower joints of a cane contain richer and purer juice than the upper or less ripe joints. The yield of cane varies greatly. In the deep volcanic loams of Hawaii, assisted by irrigation, as many as 100 tons of rich canes per acre have been obtained. In Java, where plant canes only are reaped, and the crops alternated with rice and beans, 30 to 40 tons form an average return. In the West Indies 20 to 30 tons per acre are normally grown, although heavy yields are obtained under exceptional conditions.

The purity of cane juice, *i.e.* its freedom from constituents other than sugar, depends upon its degree of ripeness. After the arrowing season, in which there has been an intense manifestation of vitality, and a noticeable increase in the impurities and the uncrystallisable sugar of the juice, the latter decreases in quantity, while the crystallisable sugar increases. At the same time, the proportion of other organic and saline matter diminishes. As, however, the maturity of the contents of the individual

joints is less towards the upper part of the cane, a condition of perfect ripeness is never found in the cane juice as expressed in manufacture. In composition the uncrystallisable sugar of cane juice is not distinguishable from other members of the hexose class. It is soluble in water, and possesses the maximum reducing power on oxide of copper, but it is doubtful whether it has any rotatory action on polarised light. Canes, however, which have been injured or which are over-ripe contain ordinary invert sugar as well. The fibre of the cane does not consist entirely of ordinary cellulose, but contains a considerable percentage of "xylan," or wood gum. The rind contains a large percentage of silica. The soluble organic matter found in the juice consists of a certain amount of vegetable albumen and pectin, or vegetable gum, the latter of which imparts the gummy character noticed in many unripe or badly-cultivated canes. This, however, must not be confused with the gummy character developed in cane-juice products by fermentation. The mineral matter of the cane consists of potash, soda, lime, and iron as sulphates, chlorides, phosphates, silicates, and organic salts, the latter playing an important part in sugar manufacture.

A large number of varieties of canes exist, but much complication has arisen from different names having been applied to the same variety in different countries. Perhaps the best classification is that given by Stubbs, who divides the known varieties (apart from seedlings) into—

(*a*) White, yellow, and green canes.
(*b*) Striped canes.
(*c*) Canes with solid colours other than (*a*).

Typical canes of (*a*) are the ***White Transparent*** and the ***Bourbon***. The former of these is also known as the Crystalline cane, the Green cane, White Java, Rappoe, Caledonian Queen, Light Java, Mont Blanc, and Rose Bamboo; while

the latter has for its homologues the Bamboo, Lahaina, Otaheite, Portier, Keni-Keni, and Lousier.

The *Striped Tanna* represents (*b*), and is probably identical with the Red Ribbon, Cheribon, Java Yellow, Violet Batavian, and Otaheite Ribbon; and (*c*) is characterised by the *Black Tanna*, with which the Louisiana Purple and Black Java are closely allied.

During the last ten years a new field of research has been developed in the rediscovered power of propagation of canes from seed. By this means an enormous number, running into hundreds of thousands, of new varieties have been brought into existence and cultivated with the view to the discovery of a cane which is superior to known varieties. The tendency, as mentioned above, with canes grown in this way to hark back to types from previous fertilisations, is so great, that the sowings from a single bloom or "arrow" may produce almost as many different varieties as seedlings, and by careful selection, chemically or physiologically, new varieties of cane of considerable promise have been grown. The depreciation in recent years of the Bourbon, which in health exhibited excellent all-round qualities as regards cultivation and manufacture, has led to the need of substitutes where its cultivation has had to be abandoned, which, while representing its past good qualities, will be free from the liability to disease and the attacks of pests which the Bourbon has lately shown. Considerable work has been done in this direction, and, in the West Indies especially, large areas are planted in "seedling" or the new varieties of canes. The system under which these have been raised has generally been for the young seedlings to be grown and subjected to careful selection by cultivation and chemical selection in the botanic stations. Those which show promising results are then distributed to the estates, where they are further tested under the estates' conditions of cultivation. The

best are then selected and extended. As the result of an enormous amount of toil, a couple of dozen, perhaps, of new varieties of cane are in general cultivation, yielding well and showing great powers of resistance to disease. Attempts are now being made to effect the cross fertilisation of known varieties. These promise to be successful, and in consequence the work of experimentalists in this direction will be considerably simplified.

The sugar-cane is liable to the attacks of both insect and vegetable pests. Several varieties of "borers" which attack the cane are known, the principal of which is the "moth" borer. The eggs are laid on the leaf of the cane, and the caterpillars from them find their way through the softer part of the rind near the joint, excavating tracks in the interior. Another borer commonly found is the shot-borer, a beetle which makes small shot-like holes in the rind of the cane. The main damage, however, is done by the moth-borer, fungus pests finding their way through the holes made by it, thus causing growths which spread throughout the body of the cane. The boring beetles are only supposed to attack canes which have become diseased in this way. The brown hard-back has of late, particularly in Mauritius, been productive of much damage.

The fungoid diseases of the cane are many, and roots, stems, and leaves are all liable to become attacked by their especial enemies. It may be taken, however, that a healthy cane—a cane which has its proper rind strength, and is constitutionally sound—will not be subject to these diseases to any considerable extent. Directly, however, the health of the cane suffers from any cause, it becomes liable to disease. The principal diseases of this description by which sugar-cane has been attacked in recent years are the rind and root fungus, so prevalent in the West Indies, the Sereh disease of Java, the gumming disease of Mauritius, and the mosaic disease. The rind fungus is so called because

it makes its appearance at a late stage in the form of dark discolorations in the rind. In the root fungus the canes gradually die from destruction of the roots by a fungus, which appears covered over with dark red spots. In the Sereh disease there is a general dwarfing of the plant, with reddening of the stalk and tissues. In the gumming disease growth ceases, the leaves turn yellow, and the fibro-vascular portion becomes charged with a yellow gummy matter. With the mosaic disease, the leaves become mottled, and exhibit symptoms of chlorosis, the stool ultimately dying.

The reaping of the cane is invariably done by hand, the luxuriant habit and recumbent tendency of most of the varieties profitably cultivated rendering machine reaping a matter of extreme difficulty. The knife used for cutting is a cutlass or "machete," which forms a handy tool for the purpose. The cane is first severed from the root as low down as possible, the upper part, which is unfit for grinding, cut off and the lower part divided, if necessary, into lengths suitable for loading and grinding—generally of about 4 feet. The cut canes are then transported to the mills, either by carts in the case of small factories, or in waggons by the tram or railroad system. In British Guiana and the Straits Settlements, water carriage is employed, flat-bottomed barges or punts being used, drawn by mules or oxen. In hilly countries rope transport is frequently used.

With reference to the employment of light railroad systems, it is important to mention that the greatest care and attention should be devoted to a judicious selection of the best and most suitable type and gauge of rail-road to be adopted for any given locality. This gauge, when finally selected, to be universally used throughout such locality with the obvious object of ensuring maximum facilities of transport, and interchange of locomotives and cane-waggons, coupled with a minimum expenditure on new connections and junctions, as well as repairs and general up-keep.

CHAPTER II

THE CRUSHING OF THE SUGAR-CANES AND EXTRACTION OF THE CANE JUICE

THE sugar-canes having been cultivated, reaped and conveyed to the sugar factory, the sugar, in the form of cane juice, has to be extracted from them, and the extent to which such extraction should be pursued has to be determined. The amount of contained sugar may vary, as sugar, from 8 per cent. to 16 per cent. of the weight of the cane-plants, although, fortunately, the lower figure is very rarely seen; or, if estimated as juice, from 84 per cent. to 92 per cent. on the same weight of these plants. Is then the whole, or only a portion of the sugar to be extracted? On the impulse of the moment, it might appear to most people that every particle of juice procurable should be withdrawn; and, taking into consideration the time, labour, and expense which have been spent on the cultivation of the plants, it does at first sight seem to be a shortcoming not to obtain the full fruits of past efforts. Much depends, however, upon the state of the sugar market, and the consequent price obtainable for the finished product. Possibly, in time to come, when the question as to the best treatment of residuals and by-products is amplified and perfected, and wider market-areas have been found for their sale, a stage may be reached when maximum extraction will be regarded as imperative. Undoubtedly the attainment of this goal of perfection would be highly satisfactory, and would close the door to much unprofitable and partially-formed

criticism which is frequently lavished on the colonial sugar industry. It would also ensure a maximum return upon the expenses of cultivation, which is otherwise only partially realised. In some localities, where special conditions prevail, these questions concerning extraction have in the present day to be most carefully considered, and a limit has scientifically and commercially to be fixed beyond which it is not desirable to proceed. Notwithstanding the perennial existence of the above considerations in many sugar-growing countries throughout the world, there is an evident determination in some quarters, where conditions more favourable to complete extraction exist, to press the question of exhaustive extraction to its full limits, and accessories of various descriptions are being employed towards the consummation of this important and desirable object. The use of old appliances, which had fallen somewhat into disuse, has been revived, together with the introduction of additional machinery of a novel description, all of which will be noted in the proper place; and nowadays an average extraction of some 97 per cent. to 98 per cent. of the sucrose in the cane is obtained with large and powerful mills assisted by both old and novel accessories—and one factory is claiming an extraction of 99·5 per cent. of the sugar in the canes in the form of juice, and another reports an extraction of 98·99 per cent. Moreover, it is necessary to determine the precise method of extraction which is to be adopted, and to decide whether it is preferable to employ force, as would be the case with the use of cane-mills, assisted in many cases by what is termed "maceration" (saturation of the megass with water), or whether the agency of the natural law of osmosis, which governs the operations of the various branches of the diffusion process, should be relied upon. Fortunately for sugar-planters, the respective apparatus used in connection

with both of these systems has been brought to a considerable pitch of efficiency, and much experience of the greatest importance has been gained of late years. Premising, then, that the use of mills seems so far to be preferred, a brief description must be given of the earlier and later forms of these extractors, which are offered by engineers for the use of sugar manufacturers. At the same time it should here be noted that the question of the resuscitation of diffusion is likely once more to come to the front.

In the earliest periods of sugar-making, when it was in all probability barely a commercial industry, the most

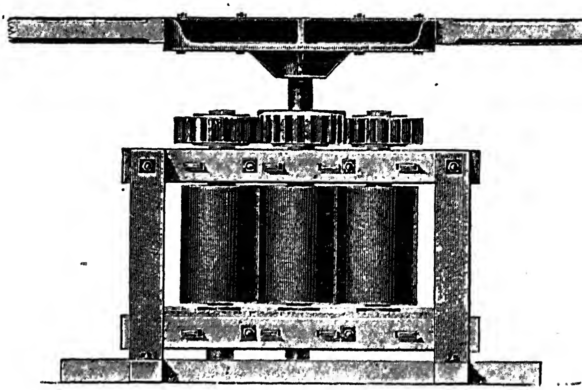


FIG. 7.—Modernised form of an elementary vertical mill.

primitive mechanical means of extraction were employed. Two or three vertical wooden rollers, contained and held in position by a wooden framework, were turned by a long horizontal lever, which was pushed or pulled by men or animals; and the passing of the canes between these rolls brought about an extraction of the contained juice ranging from 30 per cent. to 40 per cent. of the latter on any given weight of canes crushed. In some of these primitive machines no toothed gearing of any kind whatsoever was employed. In the two-roller mills one of the rolls was turned directly by the long lever, and the inserted canes

caused the other to revolve on its axis in the rôle of a moving support against the administration of pressure. Later on, simple devices were added for the purpose of ensuring a more harmonious relationship between the movements of the respective rollers, and at a still later period improved forms of these elementary vertical machines were constructed, chiefly of ironwork; and Fig. 7 shows the

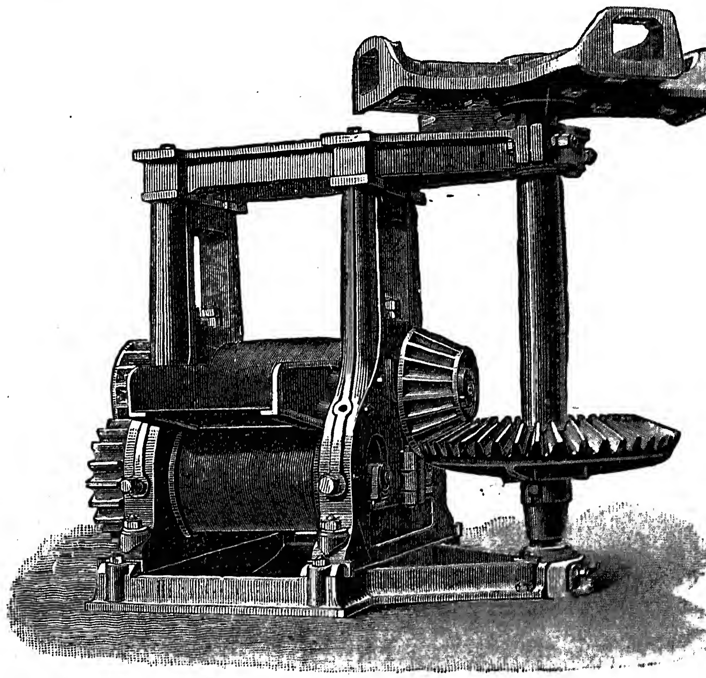


FIG. 8.—A horizontal cane-mill worked by animal power.

modernised form of such a cane-mill, with three rolls, which is still occasionally used in partially developed countries.

In course of time it was perceived that if the rollers were placed in a horizontal instead of a vertical position, the operation of feeding the canes into the mill could be conducted with greater convenience; and almost equally primitive apparatus were constructed out of wood on

ntal lines, with a simple form of additional gearing verting the prime vertical movements into horizontal 1. In its turn, this form of cane-mill was also made al (see Fig. 8). This evolution was speedily followed

FIG. 9.—A wind-driven cane-mill on Thibou's estate, Antigua.

arch for the best means of dispensing, wherever , with man and animal power as prime movers, dmills and water-wheels were attached to these and horizontal mills, thus enlisting the aid of the forces of wind and water, and a higher percentage

of juice extraction was thereby attained, the latter now ranging from about 40 per cent. to 60 per cent. of obtained juice on any given weight of canes crushed. Figs. 9 and 10 show respectively the main features of the more modernised arrangements for driving such mills by either wind or water. These ever-changing and rapidly-varying forces of nature, however, proved themselves to be fickle and uncertain sources of reliable assistance, frequently failing to put in an appearance when most needed for the disposal and manipulation of the cane crop. Again, at uncertain intervals, the gurgling streams would become raging torrents, occa-

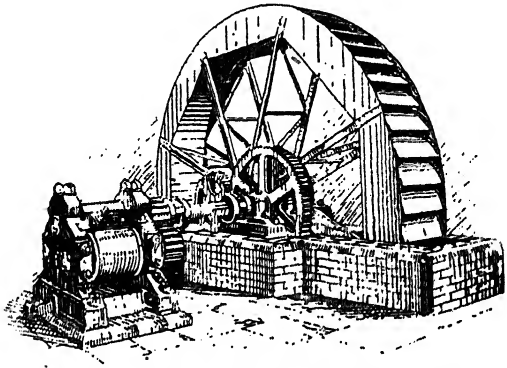


FIG. 10.—A cane-mill driven by water power.

sioning lively and inconvenient excitement in the neighbourhood of the water-wheels; or the equable breezes increased to roaring gales, which would completely lift off the tops and sails of lofty and elegant windmills, with serious concomitant dangers to life and property. But although these mishaps had to be put up with as mere possible incidents and risks in the routine of a planter's life, they tended to create a desire and a further search for some other and more reliable source of power.

In the meantime, steam had become recognised as a more sure though more elaborate motive force; and as the

appliances and materials necessary for the construction of the modern forms of cane-grinding machinery had multiplied and improved, it was found possible to employ the steam-engine as a prime mover. It was assisted by somewhat elaborate gearing which served as a medium of communication and transmission of power between the engine and the rolls of the mill, simultaneously modulating the more rapid revolutions of the engine to the slower rotary motion of the mill rollers. To this day, with greater or less elaboration, and with fewer or more numerous parts, these three combined elements—the engine, the gearing, and the mill—form the principal component parts of modern cane-crushing appliances.

It is now therefore necessary to examine the characteristic features of the above elements, and to point out their respective functions; considering next their combination as a complex whole, in the form of a complete modern cane-crushing plant, and then dealing with their accessories, modifications, and amplifications.

Fig. 11 shows the prime mover which is now most generally employed to rotate the cane-crushing rollers. It is a mechanical agent with which everybody is nowadays thoroughly familiar, and, as illustrated in these pages, it will be recognised by the majority of readers as an old acquaintance which needs no further introduction and no elaborate explanation either as to its technical details or its movements. It is, however, a separate and independent machine, and the initial element of a complete cane-crushing plant; and it should especially be noted that at the end, A, of its crank-shaft a strong steel pinion is always fixed, which is known as the crank-shaft pinion; which, though it would appear in this illustration as a part of the prime moving arrangements, is nevertheless also seen in the combined plant under the rôle of the first-motion pinion, A,

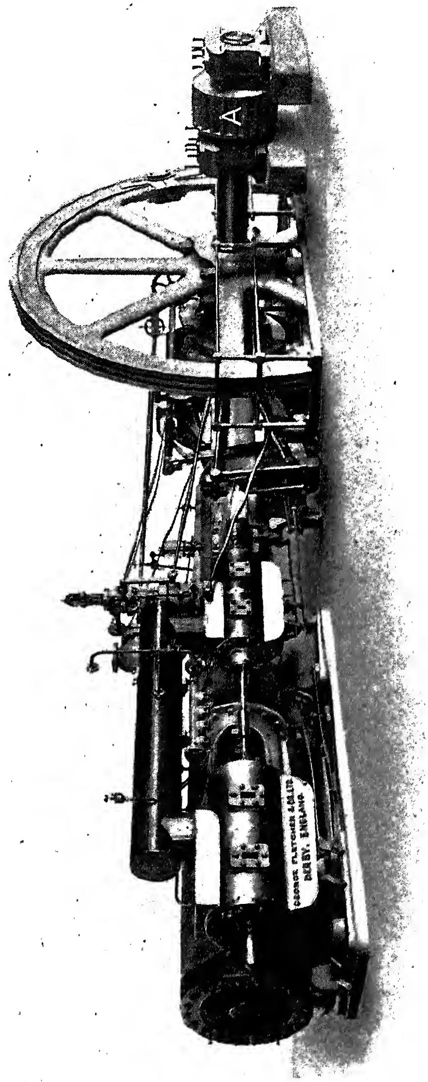


FIG. 11.—The prime-mover which actuates the gearing and the cane-crushing rollers.

of the gearing (Fig. 12). That is to say, this important detail may be dealt with under either of the two synonymous terms, " The Crank-Shaft Pinion of the Engine," or " The First-Motion Pinion of the Gearing." It is, in fact, the connecting link between these first and second elements of a complete plant; and the above references to it serve to introduce the second element. Fig. 12 indicates this compound gearing and illustrates its main features. To many people its use and necessity, as the second element of a

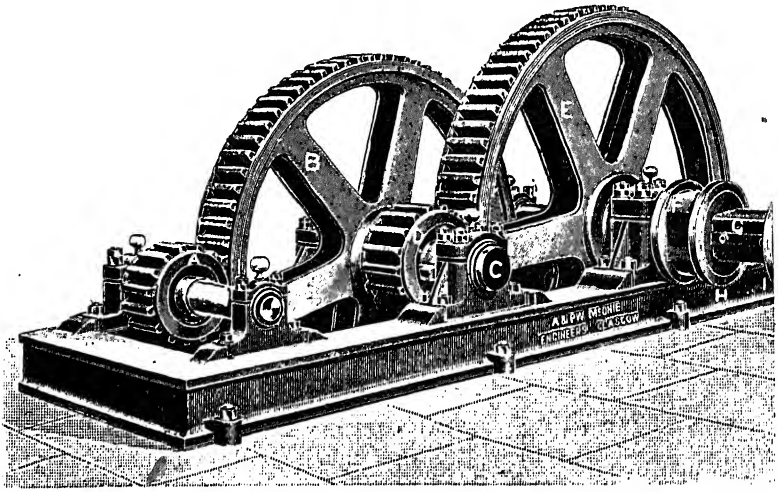


FIG. 12.—The main features of the compound gearing of a cane-mill.

complete plant, will be at once apparent after a cursory examination. The engine, or first element, is the embodiment and representative of higher speeds and more moderate forces; and for the purposes of cane-squeezing these initial forces and speeds have to be converted into much greater forces acting at slower speeds. This change, without altering the total amount of initial power engendered, is effected through the agency of the gearing now under consideration.

The crank-shaft pinion at A, in Fig. 11, otherwise (as

already explained) the first-motion pinion A, in Fig. 12, turns round at a rate of, say, forty-eight revolutions per minute, and gears with a fairly-sized spur wheel, B, some four times larger in diameter than the pinion. This wheel is called "the first-motion wheel" of the gearing, and the combination results in a speed for it of, say, about twelve revolutions per minute, and it is fixed upon the first-motion shaft, C, of the gearing. Side by side with this wheel, B, and upon the same first-motion shaft, C, another pinion, D, called "the second-motion pinion," is fixed, which in turn gears with the last and largest wheel, E, of this combination of gearing-wheels known as "the second-motion wheel." The latter will be fully five or six times the diameter of D; and E will thus revolve at a rate of about two to two and a half revolutions per minute.

The respective proportions of the above wheels and pinions vary considerably in different plants, their diameter being subservient to the varied views and experiences of the different constructors and purchasers; but the crux of the problem lies in the satisfactory attainment of a suitable speed for this second-motion wheel, E, which is fixed upon the second-motion shaft, F. As F is directly connected with the top roller gudgeon, J, of the cane-mill (Fig. 13), and therefore turns at precisely the same rate as the mill rollers, it will be recognised that the details of the gearing are so arranged as to ensure the proper number of revolutions which the mill rollers are intended to make. Thus, in the above example the cane-mill rolls also turn at the rate of about two to two and a half revolutions per minute.

It should here be mentioned that, as the speeds decrease, the strength and pitch of the gearing-wheels increase, a circumstance which chiefly accounts for the greater strength and size of the second-motion wheels as compared with the similar details of those of the first motion; and it must now

again be pointed out that the end of the second-motion shaft is connected directly to the cane-mill through the agency of the loose coupling H (Fig. 12).

A very brief consideration of the important question of mill roller speeds will now not be out of place. Much thought, and the results of extensive practical experiences, have been brought to bear upon this important requirement of a proper surface speed for mill rolls, and much has been pertinently written on the subject of "Low Speeds versus High Speeds," and vice versa. Theoretically speaking, low-speed rollers should apparently give a more prolonged

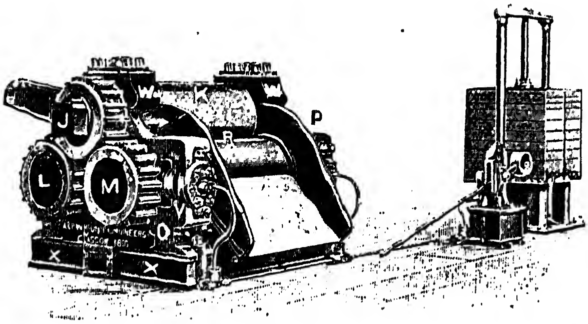


FIG. 13.—Cane-mill, with hydraulic apparatus applied to the megass roll.

squeeze to any given section of the cane under pressure, coupled with a better chance thus afforded to its contained juice to escape from the cane cells into the mill-bed, thereby minimising the ever present evil of re-absorption. In the daily manipulation and use of a cane-grinding plant there are, however, many points which demand full recognition, and existing preferences may be regarded as a compromise which tends impartially to meet the aggregate of all these requirements without giving undue prominence to any particular member of the group. Notwithstanding the above theoretical considerations, it seems evident that nowadays higher speeds, combined with thinner feeds of

canes, have been gaining the ascendancy on many sugar estates, and the details of construction of many of the most modern plants are usually found to be in accordance with this desire for higher rather than slower speeds. There is, however, in certain quarters, an evident preference under certain circumstances for a return to slower speeds, more especially with reference to the regulation of the speed of the later mills of a multiple-unit set of mills. It is unnecessary now to enter further into this particular point, and it will suffice to have touched briefly on present tendencies.

It is now therefore desirable to describe the cane-mill, which is the third element of the complete plant, and thus return to the point H in Fig. 12. The end F of the second-motion shaft of the gearing is connected, through the medium of the tail-bar G and two large loose couplings, H and I, with the top roller shaft or gudgeon, J, of the mill (Fig. 13). These two couplings H and I are purposely made to fit loosely upon the ends of the three shafts F, G, and J, so as to accommodate the varying vertical positions assumed in the course of a day's work by the mill top roller, K, such comparatively slight variations in position being due to corresponding variations in the quantities of canes which may be under pressure at any given moment. The tail-bar G is very easily removed and replaced when necessary, more so in fact than any other main detail of the mill gearing; and advantage is frequently taken of this convenience by making the middle section of the tail-bar of a somewhat lesser resisting power than is to be found in any other detail of the plant; so that, in case of sudden and undue strains, this easily handled tail-bar will give way under such strains more readily than any other part of the apparatus. This advantage is usually sought by a reduction in diameter of the middle section of the bar, as indicated at G (Fig. 12); and by this device a safeguard is

readily and economically provided against the possible breakage of other more expensive and less accessible portions of the machinery which might otherwise take place.

Upon examining Fig. 14, it will be perceived that this third element of the simpler forms of a cane-crushing plant more prominently consists of three rollers, J, L, and M, mounted on powerful " gudgeons " or shafts, held in their relative positions by two massive steel or cast-iron headstocks, O, P, which sit upon a strong bed-plate, X. These headstocks are often referred to as the side-cheeks of the mill. The relative movements of the three rollers are maintained by three massive steel pinions, fixed one on the inner end of each roller gudgeon, and the canes sliding down the feed-plate D enter the rollers at Q and emerge at R, in the form of well-crushed and heavily-pressed " megass," which, by virtue of the pressure to which it has been subjected, has been deprived of the major portion of the juice which the canes originally contained upon entering the mill. A further examination of the illustration enables one to realise that the total pressure administered is the sum and effect of two successive squeezes. The canes enter the opening Q, between the rollers L and J, and are partially crushed. Passing beneath this top roller J, they are supported and retained as a compact and comparatively non-resilient mass by the trash-turner T until they reach the point S, when they pass between the rollers J and M, and are thus subjected to the second and final squeeze administered by a three-roller cane-mill. Fig. 15 shows the effect produced upon the canes by the double squeeze; and it should be mentioned that the crushed and exhausted canes are known as " megass," which is seen in this illustration at N.

The trash-turner, T, is a most important detail of a cane-mill. It is of great strength; and its dead upper

surface, over which the partially crushed canes are pushed and dragged, is usually kept as narrow as possible in the

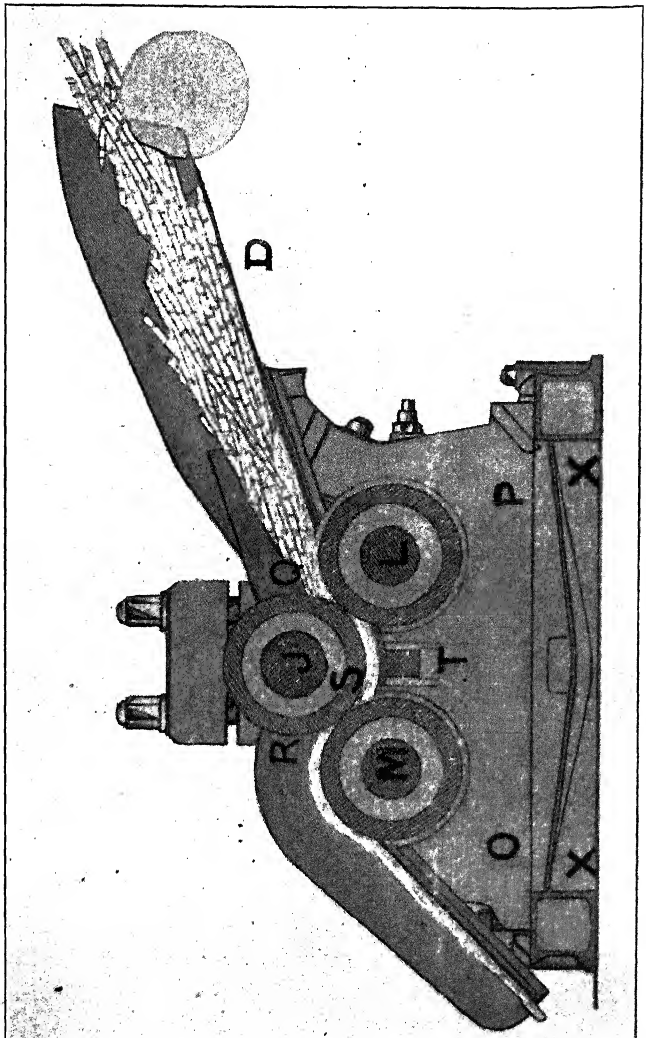


FIG. 14.—A section of a cane-crushing mill.

direction of the forward movement of the canes. Although its employment entails the expenditure of additional power

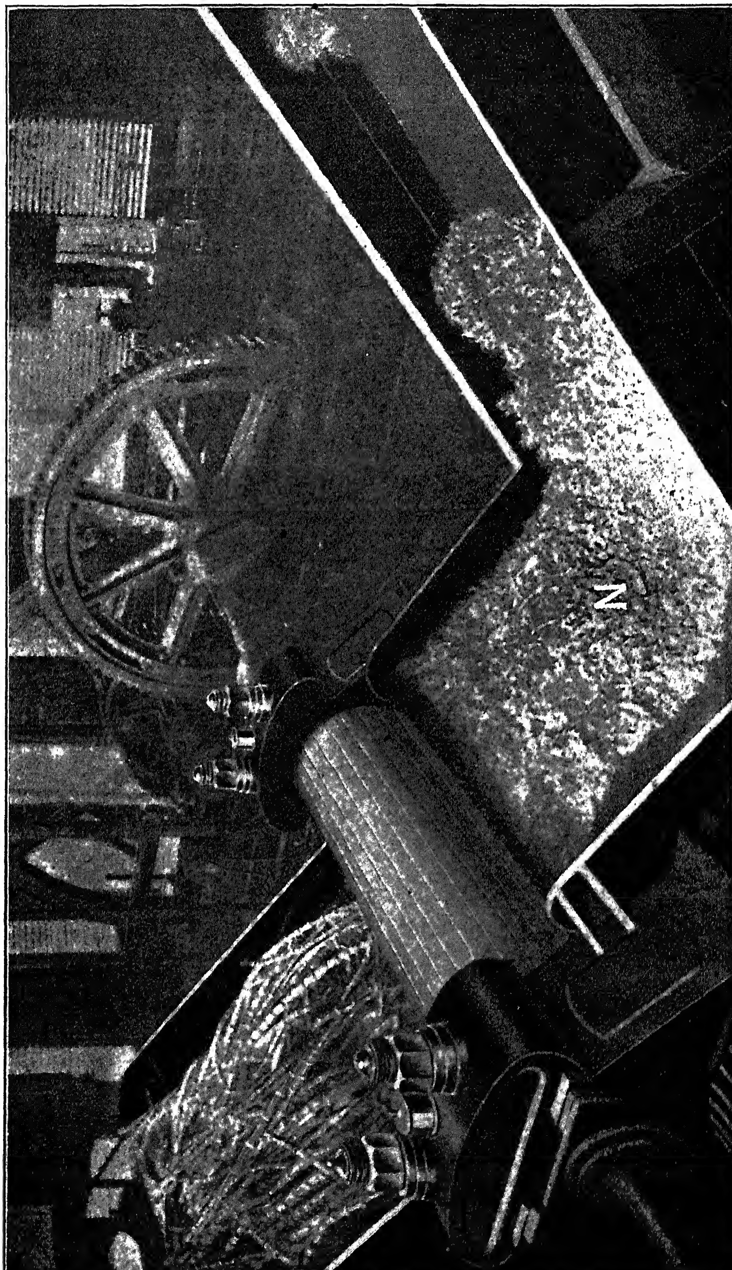


FIG. 15.—Cane grinding, showing the effect of the double squeeze.

which would otherwise not be expended, it renders nevertheless important services in return for such expenditure. Whilst acting as a necessary support and conveyer for the partially squeezed canes in their passage from the earlier to the later pressure, it also appears satisfactorily to make good and perpetuate the results of the work already performed by the front and top rollers L and J, and, if properly

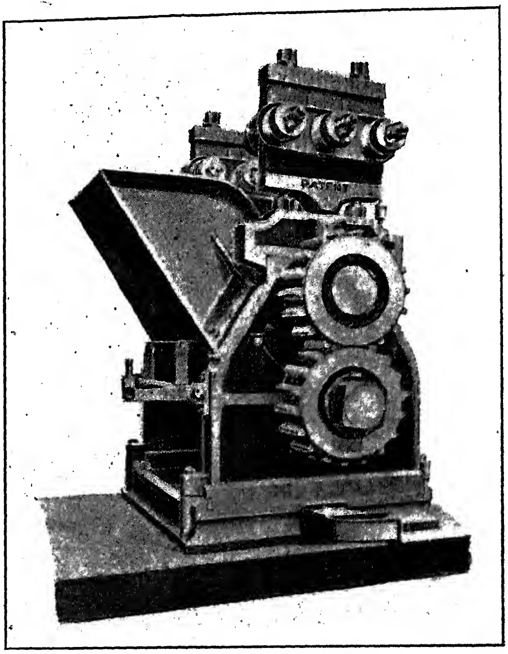


FIG. 16.—A two-roller mill.

constructed and correctly placed, minimises re-absorption, and keeps the canes under treatment in a compact and orderly mass, and thus passes them on in such a form and manner as will tend to ensure the maximum of beneficial results from the second and final squeeze.

Much attention has, of late years, been paid to the design and construction of trash-turners, and they have been the focus and subject of numerous recent patents and

special endeavours to confirm and establish their usefulness and indispensability; to increase their strength, stability and durability; and to minimise the drawbacks of their comparative inaccessibility by considerable alterations to their general form, methods of support and adjustment, together with readier means of general control, which have culminated in removing the major portion of the hitherto serious drawbacks which have consistently attached themselves to the use of this troublesome detail of mill-construction.

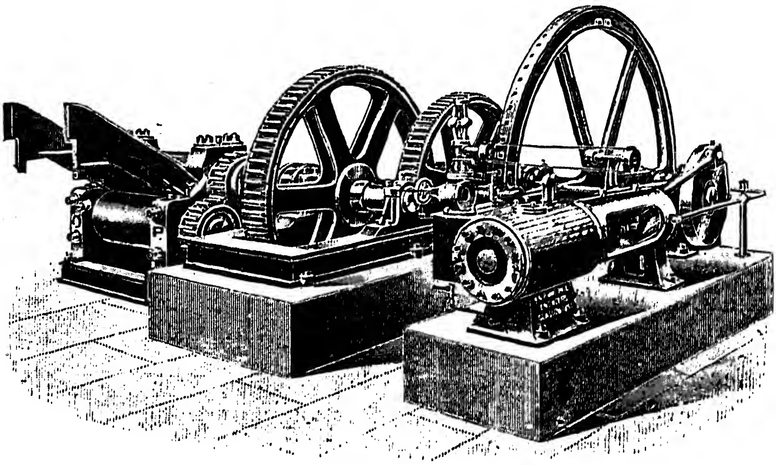


FIG. 17.—A complete cane-grinding plant.

Many devices and numerous re-arrangements of the mill rollers have been offered for the use of colonial sugar manufacturers, which have sought successfully to supplant the trash-turner. Suffice it, however, for the present to point out that one of the most obvious of these devices is shown in Fig. 16, in the form of a two-roller mill which is in use in various sugar-growing countries. Each unit of this apparatus gives but one squeeze, and two such units are customarily used as substitutes for one three-roller mill in order to give the same number of squeezes through the alternative agency of either form of mill. These two-roller

mills are sometimes used in succession to the primary employment of a three-roller mill, and in such cases they serve to administer subsequent pressure which may be applied to the megass under treatment.

It should be pointed out that the journals of the roller gudgeons are supported and held in their relative positions in the mill headstocks by heavy brass or gun-metal bearings, U (Fig. 18), which are often jacketed for the reception and passage of circulated cooling water, which aids the customary lubricants that are always applied to the inner surfaces of these bearings for the purpose of keeping both journals and bearings as cool as possible. Sometimes the bearings are also furnished with additional channels which provide for the injection of lubricants under pressure. The top roller, together with its journals and bearings, is conveniently held in the vertical gaps located in the upper portions of the headstocks. The two side rollers and their similar accessories are placed in horizontal gaps at either end of the lower portions of these same headstocks, the relative rectangular divergence of these respective positions of the upper and lower gaps being necessary for the ready re-adjustment, removal, and replacement of either of the rolls without disturbing the others. The bottom roller-bearings are of special shape, and are kept in place and proper adjustment by a unique arrangement of massive caps and bolts as shown at V. Attention should be called to the great strength of the top mill caps, W, the holding-down bolts of which pass in a vertical direction through the entire depth of the headstocks and bed-plate. Beyond this point they are prolonged through the heavy mill timbers. Upon these, each element of the cane-crushing plant is usually placed, and under the bottom side of them heavy steel washer-plates are suspended; through them the above bolts also pass to receive their large brass bottom

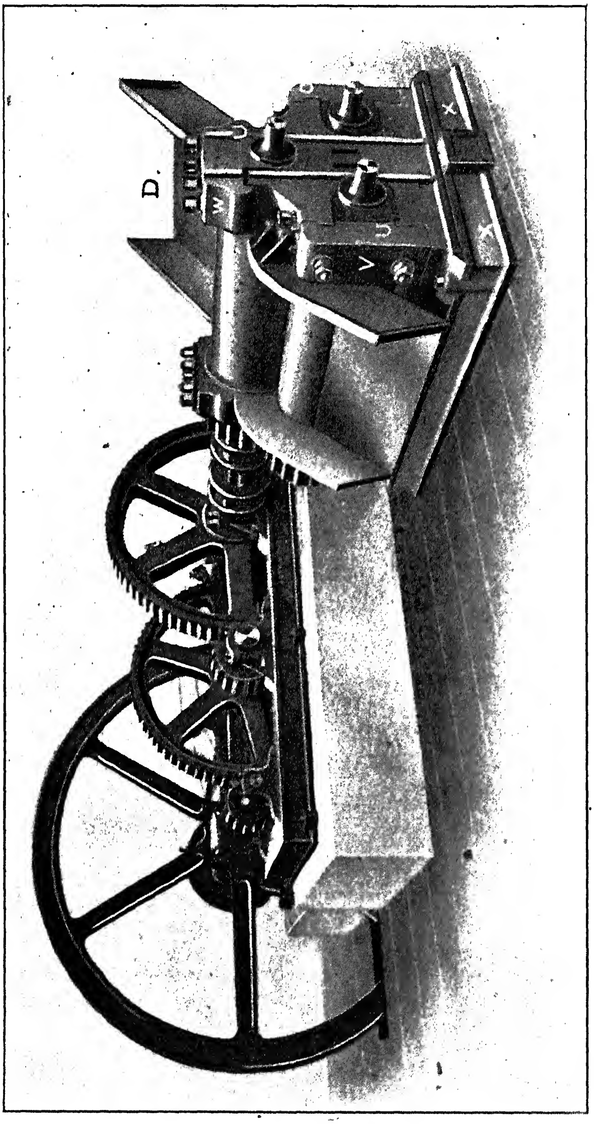


Fig. 18.—A complete cane-grinding plant, showing the engine, gearing, and mill.

nuts. By this means the bolts and caps are held down, and their strains distributed over the largest possible area of the foundations.

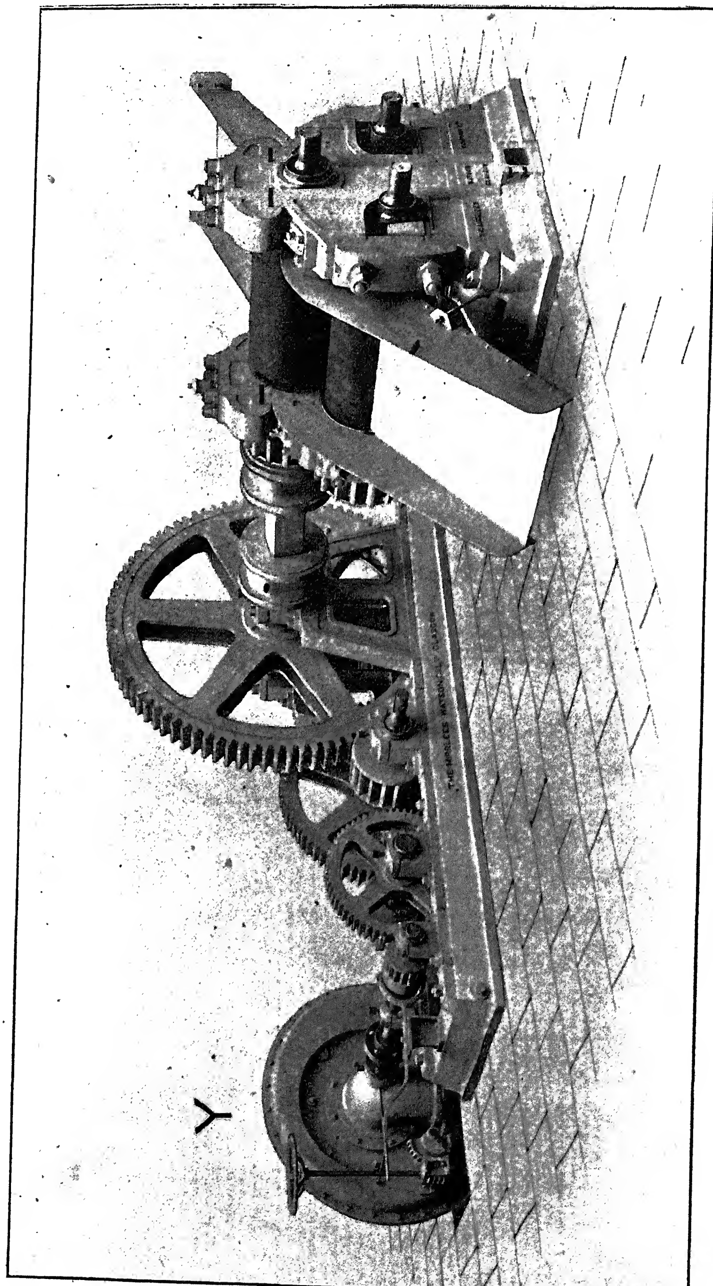


FIG. 19.—Complete cane-grinding plant driven by a water-turbine.

The two headstocks, O and P, as already mentioned, are supported by the mill-bed, X (Fig. 14), to which they are firmly secured, and this mill-bed is arranged and shaped so that it will receive and collect the expressed cane juice. It is held in position by powerful foundation-bolts of considerable length, which, passing through the timbers, protrude to a considerable depth through the massive

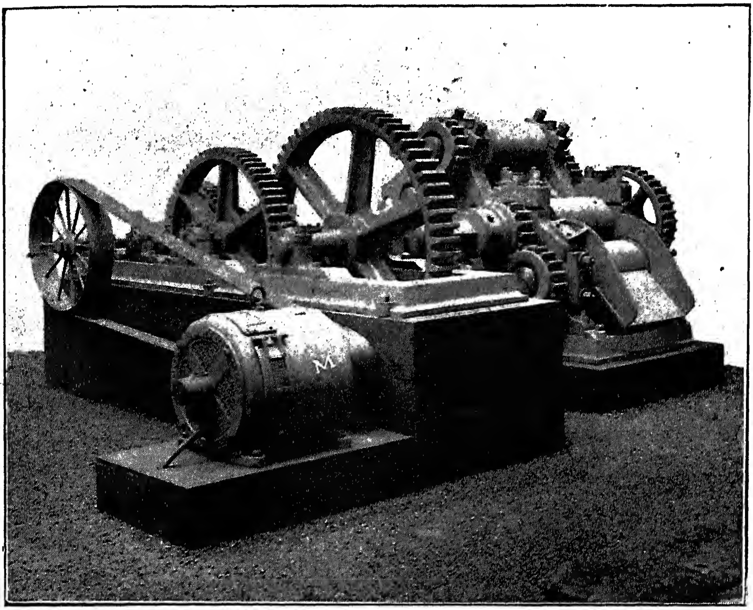


FIG. 20.—Complete cane-grinding plant driven by an electric motor.

masonry or brick-work which forms the sub-foundation for the entire plant. Both the engine and gearing are also similarly secured and held in place. Figs. 56 and 57 still further elucidate the major portion of the above details in a manner that will be readily understood.

Many other interesting details, besides those already described, might be singled out and commented upon with regard to their respective relationships, to the engine,

gearing, and mill; but for the present it should suffice to call further attention to Figs. 17 and 18, which show the above three elements combined as a complete cane-grinding plant, indicating their relative positions and functions, and exhibiting their numerous details. These illustrations, taken in conjunction with their predecessors, should enable readers to form a fairly close acquaintance with the rudimentary form and arrangement of all modern cane-grinding plants, whether loaded with numerous accessories or kept down to the point of extreme simplicity; and these various accessories will now be described—the question of multiple mills and their working being subsequently dealt with, and the comparative value of the respective results obtained in connection with the extraction of the cane juice from the sugar-canes by the employment of diverse and more complicated forms of these agencies considered. In order to complete reference to the various prime movers used to drive the smaller sizes of cane-grinding machinery, the reader is referred to Figs. 19 and 20, in which it will be seen that a turbine, Y, may be used when convenient in place of a water-wheel, or an electric motor, M, in place of a steam-engine.

CHAPTER III

ACCESSORIES AND THEIR FUNCTIONS

The various accessories, which can be added as desired, to the elementary cane-crushing plant just described, have now to be considered. Strictly speaking, an "accessory" is that which belongs to something else as its principal, acting in support of this principal without being indispensably necessary; and in the case of small-sized cane-mills one frequently finds them being used without the help of any of the accessories now about to be explained. For instance, there are cases in which the canes are fed into the mill rolls by hand, without the aid of a cane-carrier. Similarly the megass is removed by hand from the mill, instead of by means of a megass carrier or elevator. Sometimes, when the position of the mill in relation to the boiling-house permits, the expressed juice runs from the mill to the clarifiers by gravity, and a juice-pump is thus dispensed with; and preliminary cane splitters and crushers have in past times been regarded by some planters as comparative luxuries. Maximum simplicity can, however, only be retained by a considerable sacrifice of maximum efficiency; and in order to maintain the latter, and at the same time economise the employment of manual labour, it is desirable whenever possible to adopt most of these accessories. But when the mills exceed a certain size and capacity, many of these appliances cease to be accessories in the strict interpretation of the term. They then become virtual necessities, and, as such, are found to be in use in all sugar factories of even moderate size and completeness.

Figs. 21, 22, and 23 show the cane-carrier, or first accessory, which, provided no unloading mechanical appliance is employed, is the first mechanical appliance with which the canes are brought into contact upon their arrival at the factory. It takes the place of a gang of labourers who would otherwise be feeding the canes direct into the rollers by hand, and it enables the feeding of the mill to be performed in a regular and efficient manner. It consists of a strong wood or iron framework of considerable length, the initial portion of which is level and fixed at a suitable height above the ground or water level, as seen at A to B. Along the upper surfaces of this fixed level frame a slowly moving and continuous apron is arranged which is always travelling in the direction A to B, on to which the

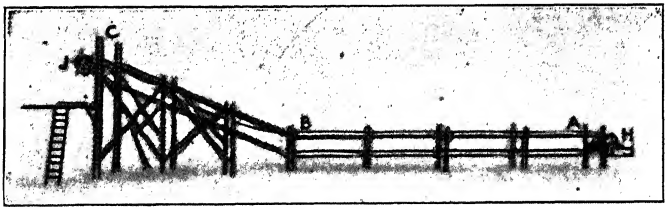


Fig. 21.—Elevation of framework of a cane-carrier.

canes are thrown for transmission to the mill rolls. It is chiefly at this stage that the canes are suitably arranged, both as to quantity and uniformity, thereby ensuring an even supply of the material to be operated upon in such a form as to promote the efficiency of the work done by the rollers.

A stationary "dividing board," or plate, placed lengthwise along the centre of the horizontal portion of the travelling-apron A, B, has a most beneficial effect to the extent of a 10 per cent. to 12 per cent. increase in the amount of work performed by any given mill. It is important for the canes, more especially the lower layers, to be

laid lengthwise upon the carrier in as regular a manner as possible, and this dividing plate appears to ensure a close and sufficiently practical approximation to this desirability without any serious elaboration of appliances and without any increased special attention on the part of the workmen in attendance upon the carrier. It is, in fact, an ever-present self-regulator of the approximately correct position of the canes, and should hang from the roof of the cane-carrier house and be steadied by a rear attachment to the outer end of the carrier, and a carefully designed

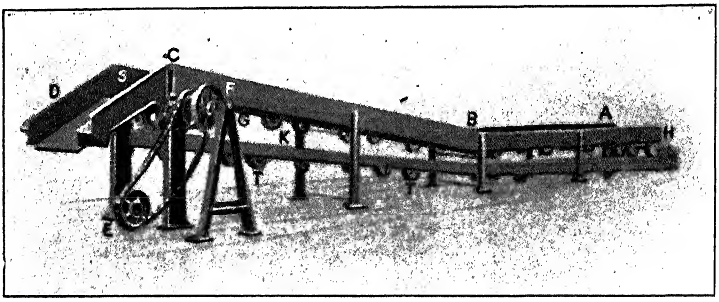


FIG. 22.—Side elevation of a complete cane-carrier.

and constructed dividing plate is well worthy of more than ordinary passing attention.

The level portion of the cane-carrier can be made of any length requisite for the convenient manipulation of the canes under varying conditions, and in cases in which they are brought from the fields to the factory by rail, the trucks are run on branch lines along either side of the carrier, the canes being then conveniently pushed out of the trucks on to the travelling apron, either by hand or mechanically. Where water transport is employed, the cane-carrier stands within a large dock, and the punts are floated alongside the carrier, the canes being thrown by hand, or lifted bodily in large masses and deposited upon the travelling apron by

means of very ingenious mechanical contrivances, which, as with the truck system, have for their object the saving of manual labour and the convenient manipulation of enormous quantities of canes at low cost.

Referring again to Figs. 21, 22, and 23, it will be noticed that at the point B the carrier inclines upwards towards the point C, thus elevating the canes to the height requisite for their convenient insertion between the mill rolls; and it is at the latter point that the cane-carrier joins the cane-plate, or feed-board, D, of the mill. This feed-

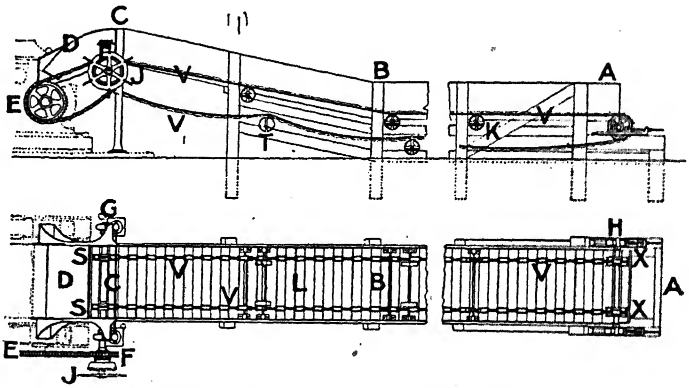


FIG. 23.—Plan of a complete cane-carrier.

plate will also be readily recognised in each of the illustrations of the mill which have already appeared, and its function as the connecting link between the cane-carrier and the mill will be fully realised. A downward change in the direction of the canes takes place at the point C, and the feed-plate D approximately slopes at a tangent common to the circumferential surfaces of the two rolls which administer the first squeeze of the canes. Great attention should be paid to the correct placing of the feed-plate D at an efficiently working slope, and the precise angle at which it ought to be fixed will vary more or less

according to the class of work it is required to perform, whether with canes or single or multiple-crushed megass.

It is now desirable to give a concise and general description of the details of construction of the above carrier, together with some explanation of the manner in which it receives its motion. E is a pitch-chain wheel mounted on the outer end of the gudgeon of the cane roller. It communicates its motion, through the agency of a strong pitch-chain, to the upper pitch-chain wheel, F, fixed on the carrier driving shaft, G, upon which are also fixed two open double and single link-chain cant-wheels, which occupy their correct position between the upper side-boards of the carrier as seen at S. A friction clutch, J, is also mounted on the driving shaft, G. At the far end, A, of the carrier another shaft, H, is fixed, furnished with a pair of cant-wheels, X, corresponding with those at S, and around these four wheels travel two strong endless bands of steel links, V, to which are attached cross slats of wood or iron, L, thus forming the slowly travelling apron or table on to which the canes are thrown. By these means a continuous conveyer is furnished which can be instantly started or stopped at will through the agency of the friction clutch, J, at which a labourer stands for the purpose of controlling the supply of canes to the mill rolls. The chains and slats, L, of the upper and advancing portion of the carrier are supported either by runners or bearing-wheels, shown at K; the lower and returning portions being similarly supported, as seen at T; and with regard to the driving of the carrier, it should be observed that in some cases spur-wheel or bevel gear is used in place of the pitch-chain wheels, E, F, for transmitting motion from the mill to the carrier shaft.

Before closing this description of cane-carriers it is necessary particularly to mention that in the case of

modern installations of cane-crushing machinery it is considered the best practice to place the horizontal portion, A, B, of the carrier as low down as the ground-level, thus facilitating in a high degree the discharging of the canes on to the carrier. In other words, the framework of this portion

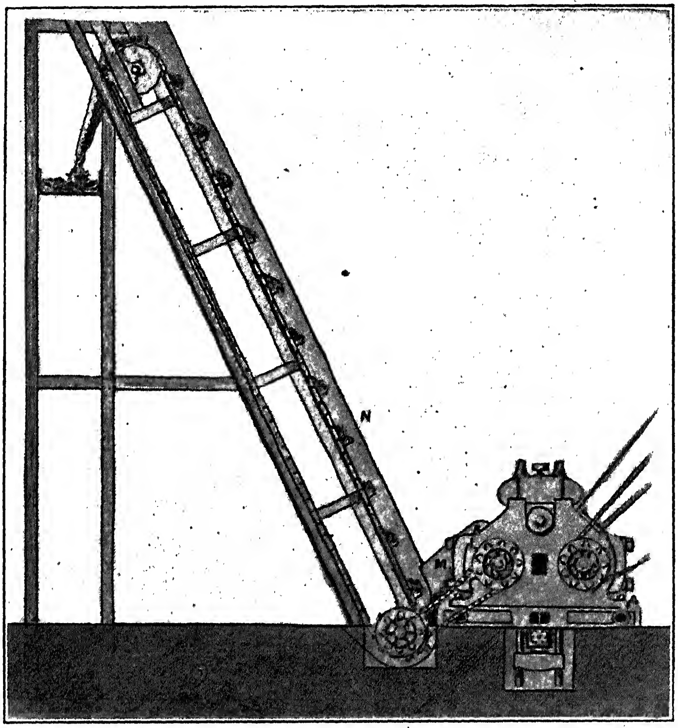


FIG. 24.—Side elevation of megass carrier or elevator.

of the carrier is located in a well-drained brick-lined pit of ample size and suitable arrangement.

After the canes have passed through the mill, and have emerged from the rollers in the form of megass (see Fig. 15), the latter slides down the steeply inclined megass-plate, M (Figs. 15 and 24), and falls on to the megass elevator or

carrier, N, which is the second accessory. The latter either conveys the megass to the boiler furnaces, where it is used as furnace fuel for steam-raising purposes, or (in cases where multiple mills are employed) first passes it on to the next mill for further squeezing before it goes to the furnaces. This megass conveyer, although actuated in much the same way as the cane-carrier, which in general construction it closely resembles in many ways, is nevertheless frequently modified to various varieties of forms to meet particular cases. Sometimes it is fully as wide as the latter, and is slow-moving, at others it is narrow and quick-running. Frequently it is of strong build, like the cane-carrier, or at times it is of very light construction, in accordance with the particular class of duty it is called upon to perform. Sometimes it is furnished with wooden cross-bars or iron rakes, which drag the megass over and along a smooth wooden flooring (Figs. 15 and 24); at others it is furnished with wood or iron slats, which form both floor and conveyer, as in the case of the cane-carrier. As these diverse forms of conveyance will be illustrated when dealing with the subject of multiple mills, it is unnecessary to describe them at greater length at present. Suffice it to say that it is impossible to cope with large quantities of megass without the assistance of such conveyers and elevators.

The other accessories with which it is desirable to deal may now receive attention. A description has so far been given of a cane-crushing mill actuated by gearing and a steam-engine, which is supplied with canes through the agency of a cane-carrier, the megass from the mill rolls being carried forward by means of a megass elevator or carrier. The next accessories to be considered have reference to the best methods of ensuring safe and efficient crushing of the canes. As already explained, the top roll

of the mill is held firmly down to its work by massive caps held in position upon the tops of the journal brasses by powerful bolts which extend downwards to the strong washer-plates situated beneath the mill timbers. It is evident, in the first place, that should hard foreign bodies of considerable size find their way into and amongst the mass of softer canes, the bolts and other mill fittings are strong and rigid enough to prevent the top roll from lifting sufficiently to avoid serious damage to various portions of the cane-crushing plant. In the second place, owing to the stretching of the bolts and the give-and-take of caps, brasses, washers, and timbers, it may, nevertheless, not be held down closely enough to its work to ensure maximum squeezing of thin feeds of canes. Prolonged experience of a practical nature has shown that these dangers and shortcomings are constantly present, and engineers have been led to seek means by which they may be avoided, or at all events minimised as much as possible. The above remarks apply to a lesser degree also to the two lower rollers, and, so far as efficient crushing is concerned, much may be effected by very careful attention to the screwing up of all the cap-bolts; while so far as dangers due to the intrusion of foreign bodies are concerned, these may be guarded against by a careful supervision of the canes as they approach the rollers, and many engineers and planters prefer to cope in this simpler way with the above difficulties. Nevertheless, human vigilance is at all times more or less imperfect, being liable to be non-existent at critical moments. Mechanical devices have thus been sought out which can be fairly relied upon to act as ever-present and unceasing guards against these dangers and shortcomings; and therefore two further accessories, now to be described, are largely used in the present day, and must be explained as frequent adjuncts to a modern cane-mill.

Figs. 25, 26, 27, and 28 show the simplest and most economically applied of these contrivances, which is known as the toggle pressure regulator. This "toggle," or "knuckle-joint," is a particular combination of levers which is well known, and justly regarded as an ingenious device. By means of very compact and simple elements, it

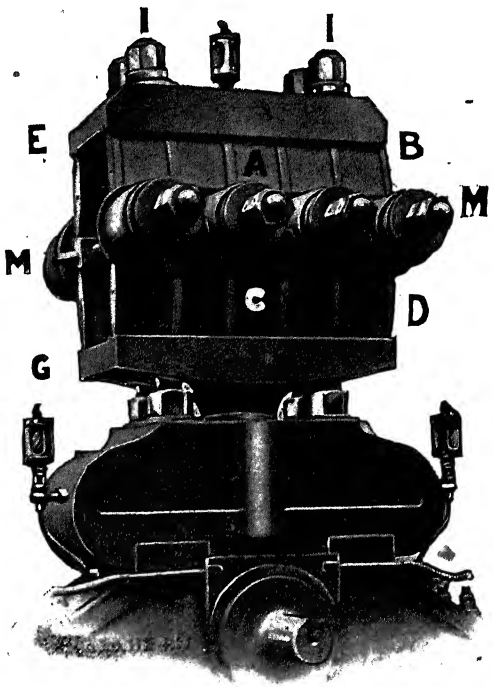


FIG. 25.—Toggle pressure-regulating apparatus.

exerts enormous force within narrow limits. Upon examination of the above figures it will be seen that the four links, A, B, C, and D, are virtually jointed at their extremities. The upper points of A and B are held to a fixed position by the top plates E and F, while the lower points of the lower links C and D are free to move vertically under

the upward pressure of the bottom plates G and H. The top plates E and F are held down as rigidly as possible by the long bolts I and J, whilst the bottom plates G and H slide up and down the shanks of the same bolts, in harmony with the vertical movements of the mill-roller and its journal brasses which act upon the plates G H through the medium of rams passing through the mill caps. When normal conditions prevail, the links, A, B, C, and D assume

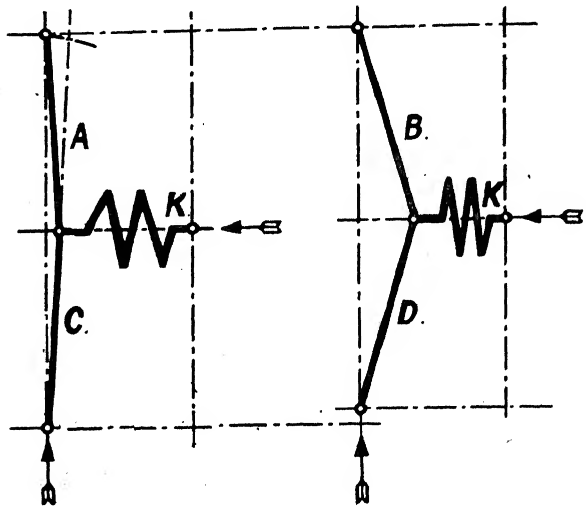


FIG. 26.—Diagram showing the lateral expansion of the toggle links with the consequent compression of the springs, due to separation of the mill rolls.

the more vertically extended positions shown at A and C (Figs. 26 and 27); when abnormal strains, due to heavy cane feeds or the intrusion of foreign bodies, lift the roller, these links assume the more horizontally extended positions shown at B and D; and a comparison of these respective conditions is clearly shown in Figs. 26 and 27. The normal position of the links A and C indicates that the mill top roller is in one of its lowest positions, whilst the more abnormal position of the links B and D shows that the

roller has been forced upwards, and these links are thus horizontally extended at the middle joints, and have compressed the buffer springs K. The springs K and L are held firmly to their duty of controlling the inner ends of the links by the horizontal through-fare bolts M, and the entire combination of the component portions of this device is intended to safeguard the mill machinery under undue

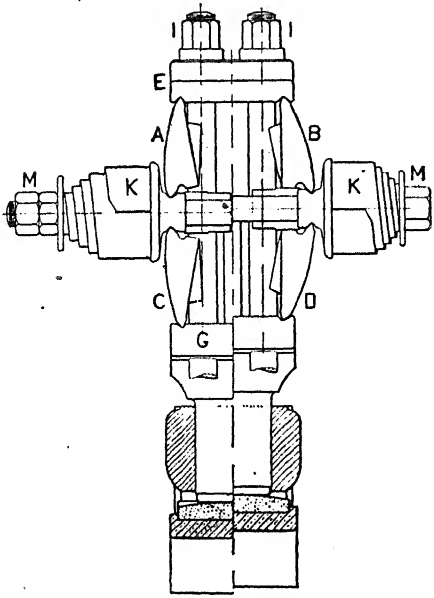


FIG. 27.—Side elevation of toggle apparatus supplementing illustration No. 26, and showing the respective positions of journal brasses, toggle-ram, plates, links, and springs under normal and abnormal pressures—normal to the left hand, abnormal to the right.

strain by allowing the roller to rise, and yield to dangerous pressures, while keeping it down to its work under normal conditions, thus ensuring a good squeezing of the canes and satisfactory extraction of the cane juice from varying cane-feeds. The various parts of this toggle apparatus are very simple, and there appears to be but little appreciable wear and tear upon them, and these recom-

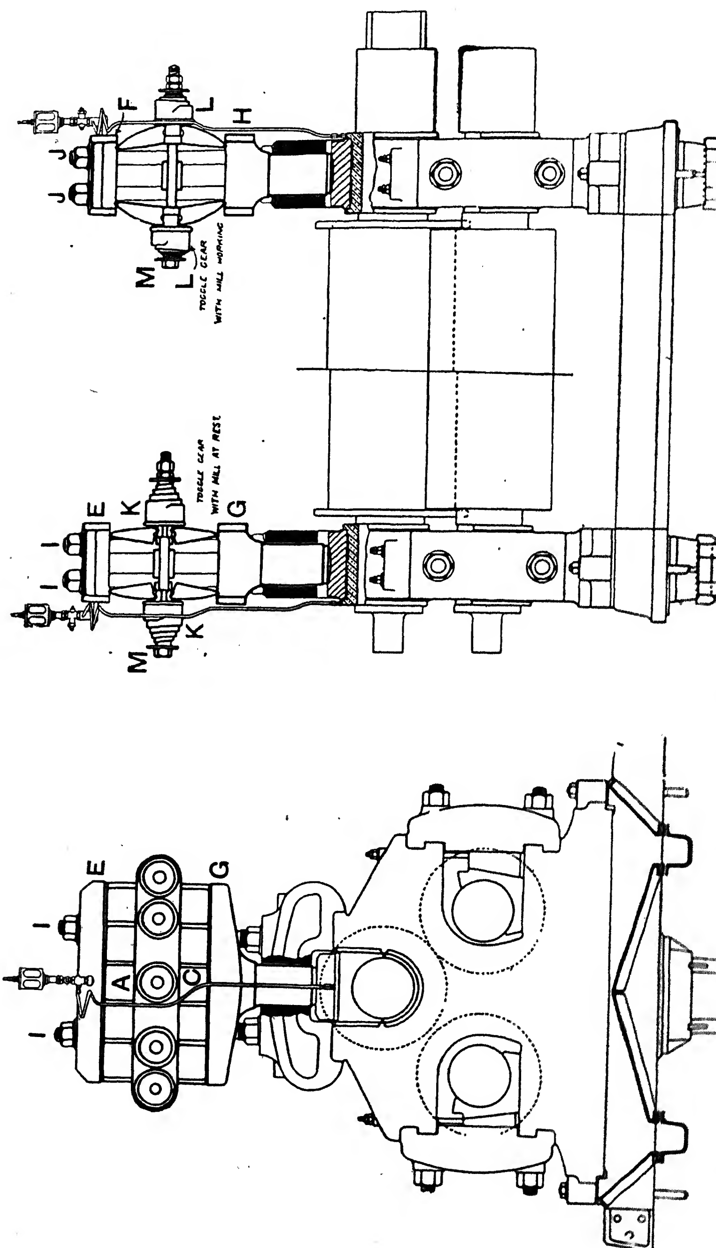


FIG. 28.—Side and end views of toggle pressure-regulating apparatus, showing their attachment and application to a cane-mill.

mendations have led to its extensive adoption on many colonial estates, where these characteristics are sought for in preference to other considerations.

An alternative and older accessory, with similar objects in view, is found in the somewhat more complicated system of applying hydraulic pressure to all or any of the rolls of the cane-mill. This is effected by the use of an accumulator placed in a convenient position in the mill-house (Fig. 13), the pressure from which is conveyed in strong pipes of small diameter to act upon rams located in the water-pressure chambers of specially designed mill caps. These rams, in turn, act upon the journal brasses, and through them exert pressure upon the gudgeons and the rolls, keeping the latter well up to their work of squeezing the canes, and simultaneously enabling them to yield more or less under abnormal and dangerous strains. Figs. 29 and 30 show how this apparatus may be applied to the top and back rolls respectively of any cane-mill, and any one conversant with the universal use of the Bramah press will readily understand the application of its fundamental principles to a cane-crushing plant. A is the force-pump supplying the accumulator with water under pressure. B is the accumulator water chamber or cylinder surrounded by the cast-iron plate-weights C, which are carried by a strong cross-head Z attached to the ram R. In the aggregate, these weights cause a maximum hydraulic pressure of some two to three tons per square inch to act upon the rams D located in the mill caps E. At the same time, each separate plate-weight is of moderate size and easily handled, and by the removal or addition of these individual weights the water pressure per square inch can be readily lessened or increased to suit the requirements of particular cases. Much depends upon the diameter of the rams D, but in some cases it will be found that the water-pressure in use does

not exceed one ton per square inch, while in others it reaches a much higher figure. The accumulator cylinder B is of sufficient capacity to hold a larger working quantity of water than is requisite to operate the shorter rams D, and when the latter are in their normal working positions,

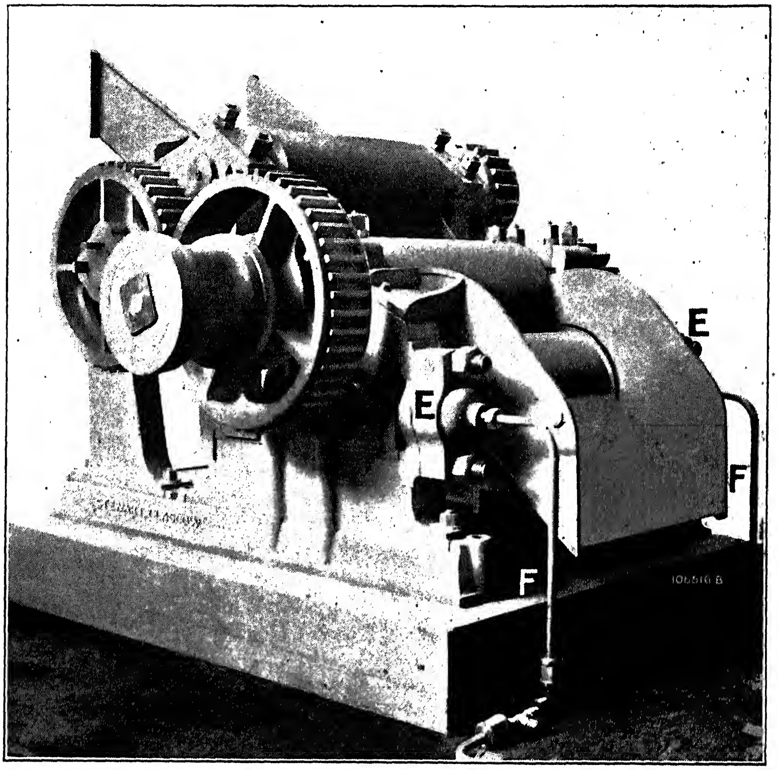
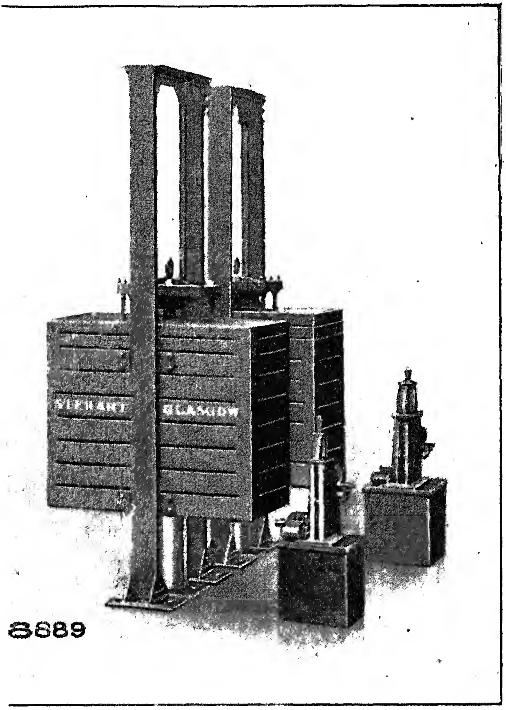


FIG. 30.—Hydraulic apparatus applied to a five-roller mill, the hydraulic pressure acting upon the megass roller.

and the mill rolls in juxtaposition, the ram R and its accompanying weights C are almost at rest in their lowest vertical position. But should a heavy feed of canesor any foreign body enter the rolls and cause the latter to separate, the water is forced back out of the mill-cap chambers E through the communication pipes F into the accumulator

and the ram R, along with the weights C, rises
› make room in the cylinder for the in-rushing
enabling the mill rolls to separate and accom-
nselves to the requisite variations of position;
time holding the rams and rollers in readiness
resume their former positions the instant that
ıl strains have ceased.



e set of hydraulic accumulators for supplying different pressures to different points of the mill rollers.

degrees of total pressure have to be used for
rollers, and for the opposite ends of either of
udgeons. These varying requirements are
et by the employment of two smaller accu-
g. 31), one of the latter supplying the higher
r the lower pressures. In other instances one

larger accumulator is made to do duty for all requirements, the requisite variations in the total pressure applied at the different points being obtained by a suitable adjustment of the diameters of the respective rams, the latter being made of a larger or small diameter according to the greater or lesser total pressure required. For instance, the top roller should be held down by a greater total pressure than would be applied to either of the lower rollers; and this total pressure would be divided unequally, the minor portion acting upon the end of the top roller gudgeon upon which the pinion is fixed, and the major portion upon the outer end of it, a converse division of pressure being arranged for the megass roller. Any of the mill rolls may be controlled by the above described methods, and have been so worked in the past; but the top and the megass rolls are usually selected, while the cane roll is very rarely called upon to work under hydraulic pressure. With high roller surface speeds and with correspondingly thin feeds of cane, it is nowadays considered sufficient to provide hydraulic apparatus for the top roller alone. It is only necessary to add that in the use of hydraulic appliances great attention has to be paid to the cupped leathers which surround the various rams and form the hydraulic joints which prevent the escape of the water from the apparatus. Oil is preferably used instead of water in the accumulator and ram chambers, with a view to keeping the leathers in good order for the greatest possible length of time.

Compressed air is, in some cases, also employed to promote ram-pressures for the mill-rollers, and in conjunction with specially arranged apparatus acts in its case in a manner similar to that of the oil and water in the hydraulic apparatus.

In all cases in which hydraulic pressure is applied to cane mills, considerable attention has been paid to various

details that will minimise the effects due to delays caused by unavoidable rupture of the hydraulic leathers. The latter cannot reasonably be expected to have an abnormally long life, and they are liable to give out at almost any moment. A temporary stoppage of the mill involved is thus necessitated, and when such machine forms a unit of a

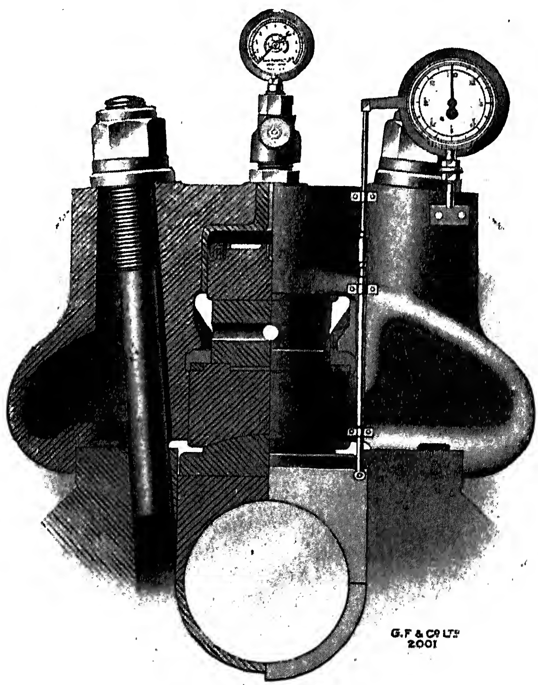


FIG. 31A.—Improved hydraulic top cap. The patent locking ring enables the mill to be locked whilst the ram is removed. The patent ram with metallic packing will last several crops without requiring any attention.

considerable train of associated mills, such stoppage attains the status of a most undesirable interruption to uniform procedure. The duration of such interruptions must therefore be curtailed to the shortest possible period, and much ingenuity has been exercised to this effect.

Fig. 31A shows the details of one well-known appliance

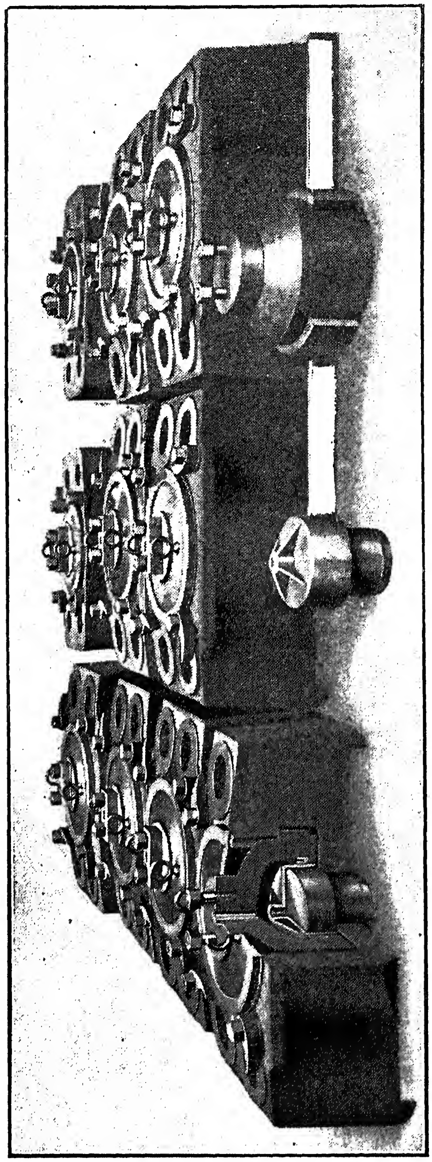


Fig. 31b.—Portable and detachable hydraulic appliances which can be readily removed and replaced.

which promptly enables the mill in question to resume its functions under screw-pressure and allows it, with

minimum delay, to proceed with its operations until a convenient opportunity occurs for the replacement of the

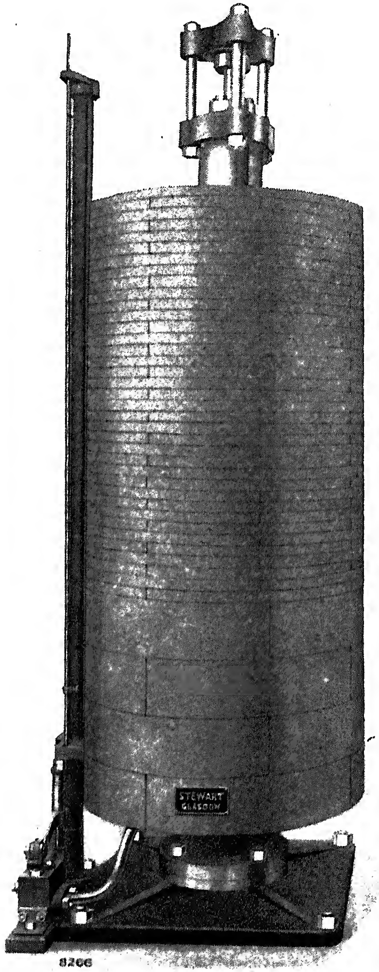


FIG. 31C.—Modern centrally guided hydraulic accumulator.

useless leather. By means of a patent locking ring it enables the mill to be worked whilst the ram and defective leather are removed and replaced (see Fig. 31A).

Fig. 31B also shows another arrangement in which the vital details of any hydraulic appliance form a separate and easily removable and replaceable detail or unit. Thus spare units are kept at hand for immediate use and can be promptly utilised without undue delay.

The employment of metallic packing for the hydraulic rams in place of leathers is also being introduced.

Fig. 32 shows another accessory which is used in several countries. It consists of a number of cane-slitting knives placed helically upon a rapidly revolving shaft which is

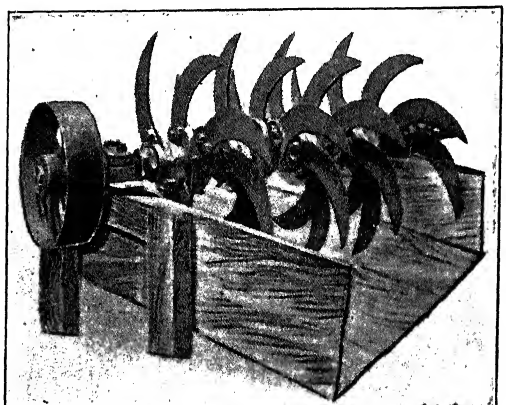


FIG. 32.—Cane-cutter, or splitter, to prepare the canes for the mill.

fixed at the head of the cane-carrier, near the mill feed-plate. It is intended to slit and open the canes to a certain extent, and so to prepare them for more effective squeezing. It also breaks the back, as it were, of the mass of canes about to enter the mill, and, generally speaking, straightens them lengthwise, in a direction towards the mill, and renders them more amenable to treatment, though it is not intended to serve as a juice extractor in any other sense of the term. Nowadays its general employment is apparently increasing and is extending, and it seems no

longer to be thrown aside in favour of crushers and shredders, but in many cases is found to be an efficient auxiliary to these more complicated accessories. Close attention is likewise being paid to the details of its construction, both with regard to the shape and length of the knives and the method of their attachment, sometimes rigid, at others pivoted.

A more important and elaborate accessory, known as the Krajewski crusher, is shown in Figs. 33, 34, and 35.

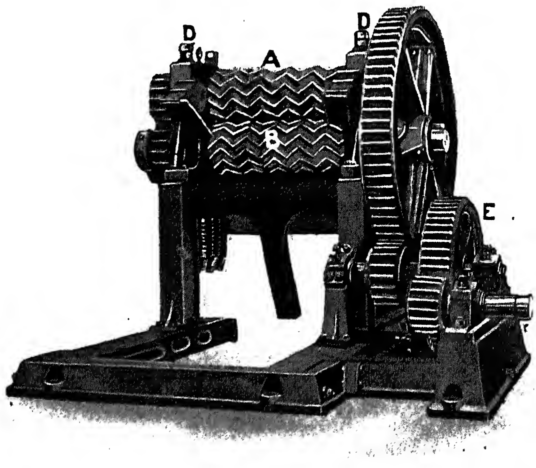


FIG. 33.—Krajewski cane-crusher, with gearing for driving.

It goes a wide step farther than the simple apparatus just described, aiming at a considerable increase in the efficiency of whatever form of cane-grinding plant it is called upon to supplement. Experience has shown that the output of the plant may by its application be increased from 20 per cent. to 30 per cent., according to circumstances. It acts as a crusher as well as a preparer and equaliser of the feed of canes on their way to the mill, and it has proved so beneficial in both respects that it is even used in conjunction with

a train of multiple mills furnished with knives and shredders.

It will be seen that the essential features of the apparatus are two solid steel rolls, A and B (Fig. 33), with pointed, zigzag corrugations extending longitudinally across each roll. These corrugations on the separate rollers are arranged to mesh but not to touch, the rolls being kept at the minimum distance apart by suitably fitted blocks,

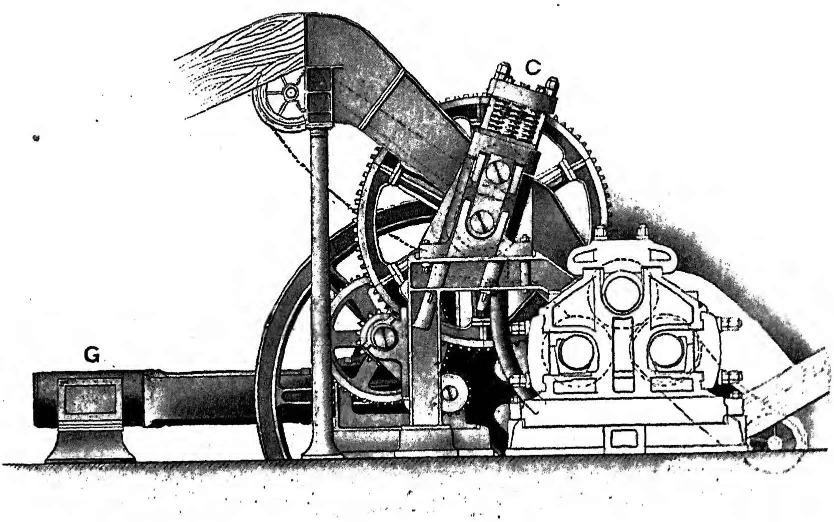


FIG. 34.—Krajewski cane-crusher, with compound spur gearing and independent driving engine, attached to a three-roller cane-mill.

whilst their degree of separation is controlled by powerful springs, C (Fig. 34), or by the application of the hydraulic appliances already described. The rolls and springs and other details are held in position by two strong headstocks, D, fitted with suitable gun-metal journal bearings; and the entire apparatus, as shown in Fig. 33, is usually placed somewhat above and in front of the mill, as shown in Figs. 34 and 35. The rolls of this machine are worked through the agency of the heavy gearing, E, which is

preferably driven by a separate steam-engine, G; and in this form the entire combination of engine, gearing, and Krajewski crusher will be recognised as being a modified and miniature replica of the elementary cane-grinding plant already described, so far as the intention and general arrangement of its elements are concerned. Sometimes the separate engine, G, and the gearing, E, are dispensed with, and the crusher-rolls are worked by an extension of the gearing which drives the cane-mill or mills to which

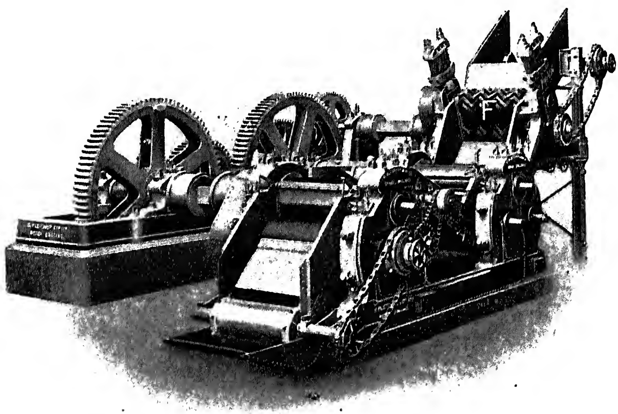


FIG. 35.—Krajewski cane-crusher driven by branch gearing off the mill gearing, instead of being driven by an independent engine.

the crusher is an accessory (F in Figs. 35 and 36). Sometimes, again, a pair of ordinary though specially grooved rollers, G (Fig. 36), are used in place of the characteristic rolls of the Krajewski crusher; and in some countries the latter are supplanted or even supplemented by cane-shredding rolls, which are worked in a manner rather similar to that described in the above references to the engine-driven crusher. In order to obtain feed efficiency approaching that of a crusher, in the absence of the latter, the top roll of the first mill is sometimes made as shown in Fig. 37.

It is important to note that, in one sense, the capacity of the Krajewski crusher, employed up to the point of its maximum efficiency, is virtually the controlling point of

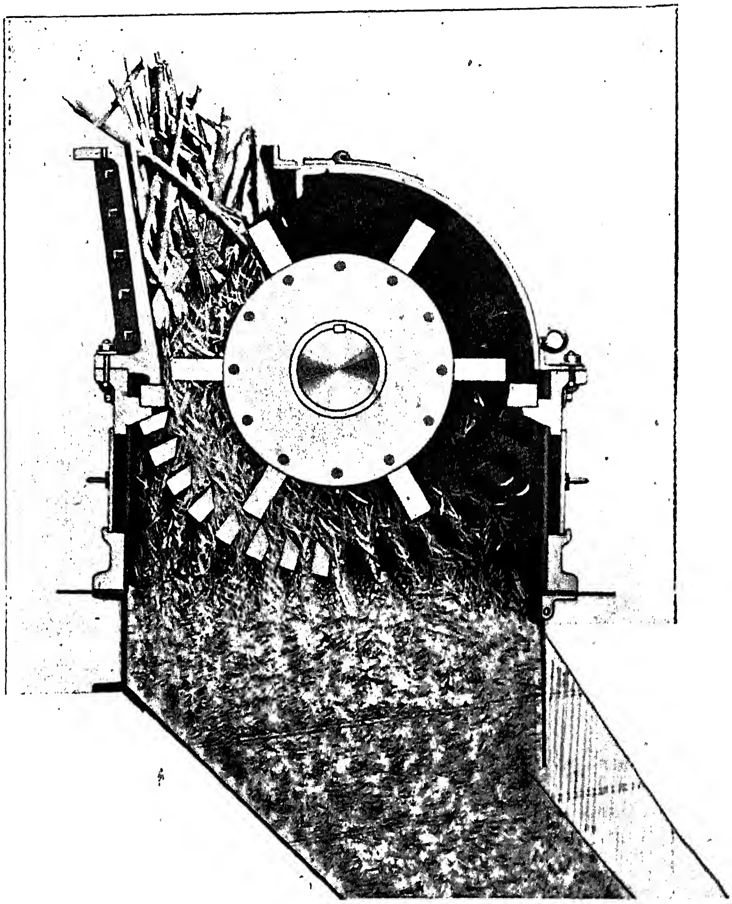


FIG. 35A.—Sectional view of Searby shredder in operation.

the maximum output of any given train of mills working in conjunction with such crusher. That is to say, that when it is unassisted by any other accessories, such as cane-knives or shredders, the importance of its services to the

following mills is such that it is a mistake to suppose that by relieving the pressure on the crusher-rolls, with a view to passing an increased quantity of canes through the crusher, an increase in the daily or hourly output of the mills will result. As a matter of fact, the total amount of work effected will thus be reduced, owing to the inferior

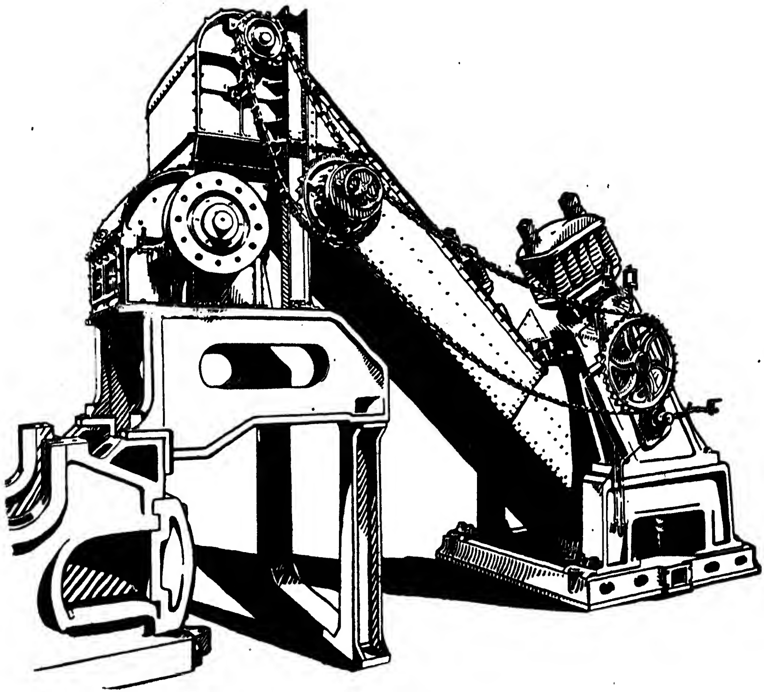


FIG. 35B.—Searby Shredder Installation.

preparation of the canes *en route* from the crusher to the succeeding mills, the latter, consequently, having such an excess of work thrown upon them that they are unable to cope with the increased quantity of insufficiently prepared canes thus passed on to them, although they would have been able to deal with this increased quantity if sufficiently prepared. In actual practice, it will be found in most

cases to be generally necessary to maintain a maximum pressure coupled with the closest possible setting of the crusher-rolls, and to be content with the quantity of thoroughly prepared canes which the crusher can thus provide. The Krajewski crusher should therefore always be of ample size and power requisite for the fullest accommodation of the train of mills it is intended to serve.

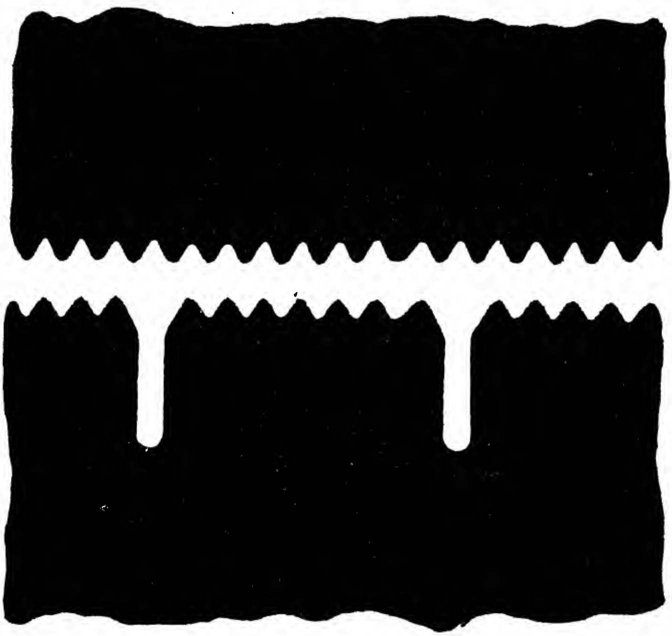


FIG. 35C.—Messchaert grooves, as applied to cane-rolls.

This particular form of crusher breaks up and partially squeezes the canes, and likewise transversely cuts them up into very short lengths; whilst another very similar crusher is largely used with the intention and result of longitudinally slitting the canes, with a view to securing a more continuous and satisfactory feeding of the succeeding mills. The employment of both of the above apparatus appears nowadays to be gradually assuming a secondary

or auxiliary position which, in due course of time, may ultimately end in their comparative abandonment, when they will be superseded by more modern appliances that ensure a thorough disintegration of the canes.

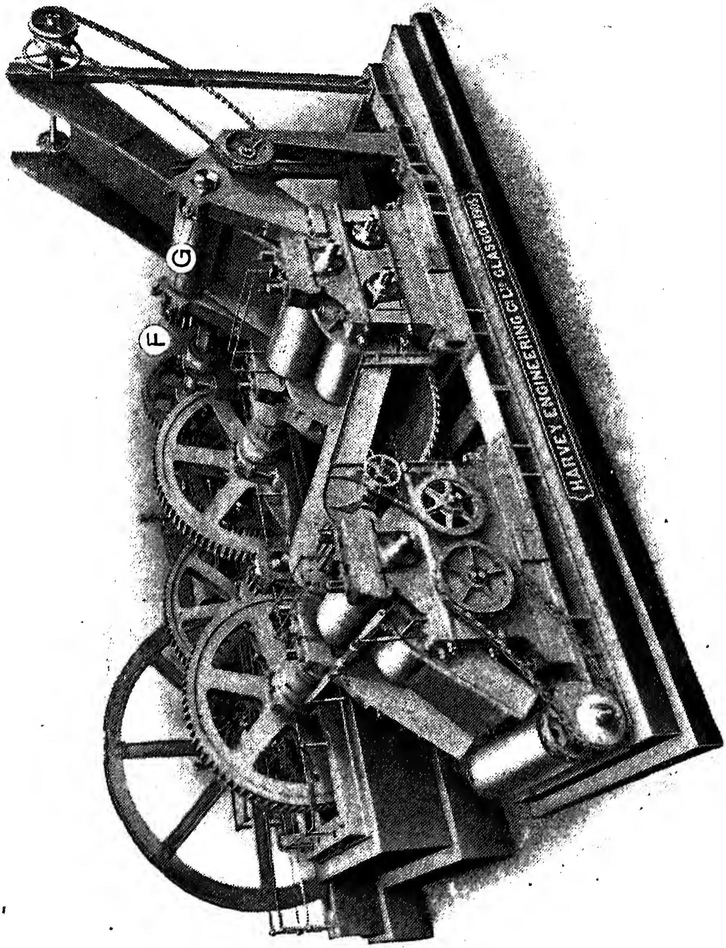


Fig. 36.—Two three-roller mills with a pair of preparatory rolls driven by branch gearing off the mill gearing.

In view of the requirements inseparable from the thoroughly efficient application of maceration water, it is nowadays found that hardly any limits are to be fixed with regard to a complete disruption of the cane-fibre,

more especially in relation to the shell-fibre of this plant. Furthermore, the capacity of the mills, as effective squeezers, both as to quality as well as quantity, is thus considerably increased in addition to the greater facilities afforded to the water for intimate percolation of the otherwise more inaccessible juice-cells of the canes, which should be completely permeated and washed by the maceration water.

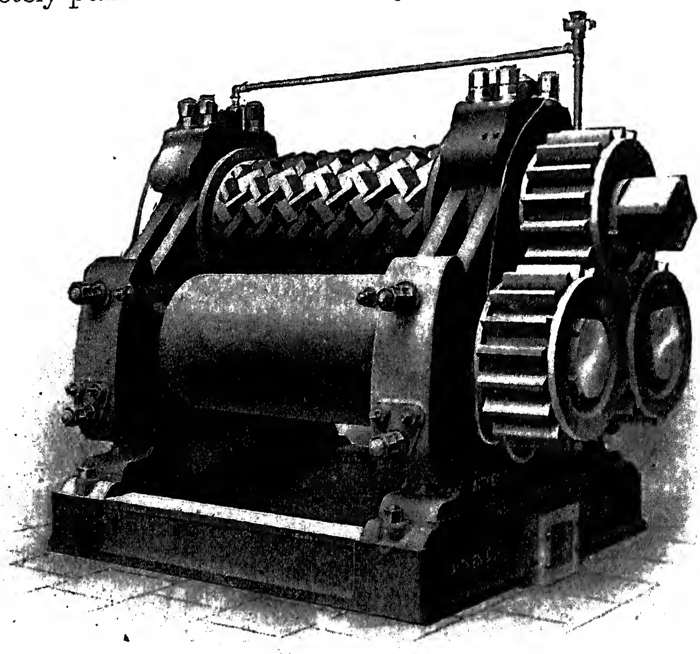


FIG. 37.—Diamond roller used as the top roll in cane-mills.

Figs. 35A and 35B show the nature, details, and application of such a modern disintegrator or shredder. As will be seen, this shredding or beating machine consists of a series of pivoted hammers, which rotate at high velocities in a casing containing suitably spaced anvil-bars, parallel to the axis of rotation of the hammers. These anvil-bars extend round a portion of the circle described by the

revolving hammers; and the latter are suspended from rods fixed in holes in the series of discs which rotate with the main shaft of the machine, upon which they are firmly secured. The hammers are thus located between the discs, and project about 6 inches beyond their circumference. The canes enter above the anvil-bars, are beaten by the hammers, and the disintegrated cane-fibre passes out between the bars. The shredded canes thus form a thoroughly disintegrated and uniform mass, in which the fibres are completely and literally separated from one another, thus providing the mills with a continuous blanket of material which offers complete access of the maceration water to the interior of the juice-cells of the canes. It is in connection with shredded canes or megass of such a disintegrated character that diffusion may possibly be resumed after the preliminary employment of a single mill of special construction, which would first remove the major portion of the juice, and thus more efficaciously prepare the megass for final treatment in the diffusion battery.

In so far dealing with the subject of accessories, we have arrived at a stage when the prepared canes are about to enter the mills, in order to attain the necessary extraction of the contained juice; not overlooking the probability or certainty that they may have already parted with a greater or less percentage of such juice in the processes of preparation above described, the percentage of such deprivation depending more or less upon the particular form of preparation they have undergone; and the opportunity should now be taken of referring to the difficulties attendant upon the important question of "re-absorption."

This *bête noire* of the operation of cane-squeezing is ever more or less present in the action of all mills, although it frequently escapes precise detection, whilst in numerous cases it is so patent to the most casual observer as to call

for prompt and drastic measures for its immediate correction.

It is unnecessary here to attempt to follow the voluminous discussions that throughout the past fifty years, and more, have associated themselves around this standing source of unsatisfactory mill-squeezing, involving a multitude of preferences for perfectly smooth rolls on the one hand, or surface grooves of varying character on the other. The broad presumption remains that, in past years, cane-mills have undoubtedly been squeezing the juice out of the canes with an unsuspected efficiency, but owing to the absence of the desirable and necessary provision of the means for an unobstructed escape of the expressed juice from a too intimate and hitherto enforced and prolonged association with its parent fibre, from which it has just been separated, it has to an undesirable extent been improperly re-absorbed and carried forward through the mills along with the megass, thus more or less detracting from the completed result of extraction that would otherwise have been secured.

One of the simplest and most efficacious methods of avoiding re-absorption is undoubtedly to be found in the application of Messchaert grooves to the lower rolls of a cane-mill.

Without entering into the refinements of this application, which is receiving careful and continued consideration and modification, it may in the first place be observed that even the simplest forms of such grooves effect remarkable improvement in juice extraction. This simpler form of groove, with the assistance of Fig. 35c, may be described as follows:

Along the full length of the lower rollers circumferential grooves, about a quarter of an inch in width, are cut at intervals of $1\frac{1}{2}$ to $2\frac{1}{2}$ inches pitch, to a depth of from $\frac{3}{4}$ of an

inch to an inch. These grooves may be applied to one or both rollers. When cut only in one roll, they should preferably be situated in the megass roller; but it is desirable that they should be cut in both the cane and megass rollers. They should, however, never be applied to the cane roller of the first mill unless such mill is preceded by a Krajewski crusher or a shredder.

Each groove is preserved from an undue accumulation of tightly compressed megass by means of a suitable scraper, which keeps it satisfactorily clear of obstructions. With proper arrangements the megass is never sufficiently forced into the grooves to prevent them from acting as thoroughly efficient drainage channels which allow the expressed juice to escape promptly and freely from the megass under pressure. Excellent results are thus obtained, combining increased extraction with a smoother and much more satisfactory working of the mills and engines. Opportunities are likewise offered for effecting useful modifications of the adjustment of the mill-rolls.

Attention must now be directed to two less pretentious accessories of an altogether different character, which perform special duties in immediate connection with the cane-mill. The expressed juice from the canes falls into the mill-bed, which, as already mentioned, is suitably formed for its collection and reception. It then runs out into a juice-tank, A, as shown in Fig. 38. In the upper portion of this tank a strainer, B, is fixed, which is intended, as much as possible, to retain the fine "cush-cush," or pulverised particles of the cane-pulp and rind, produced by the grinding action of the rollers, which is present in large quantities in the cane juice.

The "cush-cush" is mixed with any sand and other substances which adhere to the rind of the canes, and it is found convenient as well as important to get rid of these

mechanical impurities promptly, for otherwise they would injure the juice, besides choking the pump-valves and the chambers and tubes of the juice-heaters. After passing through this strainer, B, the juice falls to the bottom of the tank, where it is trapped by a removable plate which protects the pump-valves, the valve-chest, E, being fixed

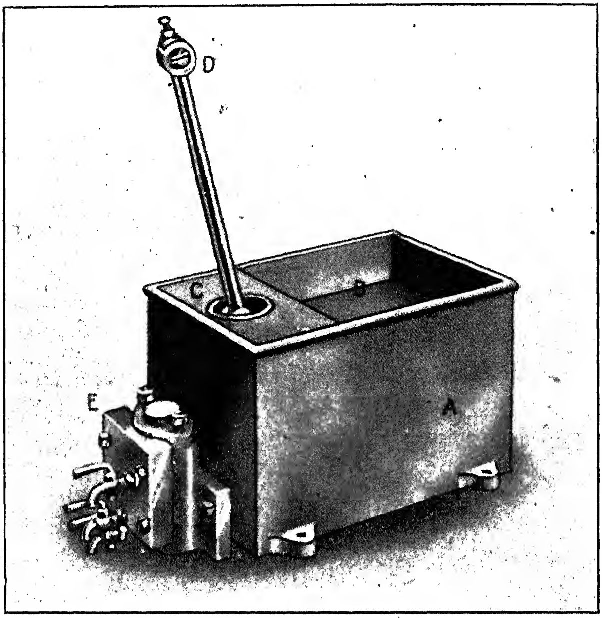


FIG. 38.—Standard cane-juice pump, with tank and strainer.

outside the tank, thus giving free access to the valve-chambers for the purpose of prompt examination. The connecting-rod, D, of the juice-pump, C, is usually attached to a disc-crank fixed upon the end either of one of the mill gudgeons or the first-motion gearing shaft, thus giving the necessary reciprocating movement to the plunger of the pump. The latter, when arranged in the standard form shown in the illustration, is necessarily single-acting, and as it makes but few strokes per minute it is therefore, com-

paratively speaking, of large diameter, the major portion of its working parts being made of solid gun-metal. In some instances, this standard form of vertical cane-mill pump is replaced by more modern double-acting horizontal steam-pumps of various kinds; but whichever type is used, its duty is to force the juice from the mill-house up and into the clarifiers, so that it may undergo the process of clarification.

The effective straining of the cane-juice at the mill is a matter which does not always receive the amount of attention it deserves. In the form of strainer shown at B there is a difficulty in obtaining as complete a separation of the " cush-cush " from the juice as might be desired. The former has to be scraped up and removed from the strainer-web by hand, and it is this very method of removal that tends to choke the interstices of the strainer through the unavoidable pressing of the finer particles of the refuse cane into the openings of the strainer-web. The finer the strainer the more readily it is choked; and the complete efficacy of the straining is therefore limited to the point attained by the employment of a comparatively coarse web, which only gives partial results. Otherwise the attendants fail to keep the strainer sufficiently clear for the reception and free passage of the large quantities of juice which are continuously pouring on to it from the mill, and they are tempted to resort to various objectionable devices, which largely nullify the full intention of the apparatus, in order that they may superficially appear to be coping successfully with a task which at times proves beyond their capabilities. In order, therefore, to obtain the best results, it is desirable to dispense altogether with hand labour, and to rely upon the automatic service of a purely mechanical arrangement. This change can be efficiently brought about by the very simple apparatus shown in Figs. 39 and 40. In Fig. 39, A

is a lightly constructed wheel of any convenient diameter, which is usually large enough to elevate the retained "cush-cush" to a height sufficient to discharge the latter by gravity on to the mill feed-plate or one of the intermediate megass conveyers. It can be fixed upon the outer end of the mill top-roller gudgeon, or, as shown in the illustration, it can be worked by a belt or light gear from any suitable source of motion, according to the circumstances of particular cases. Around its inner circumference angled

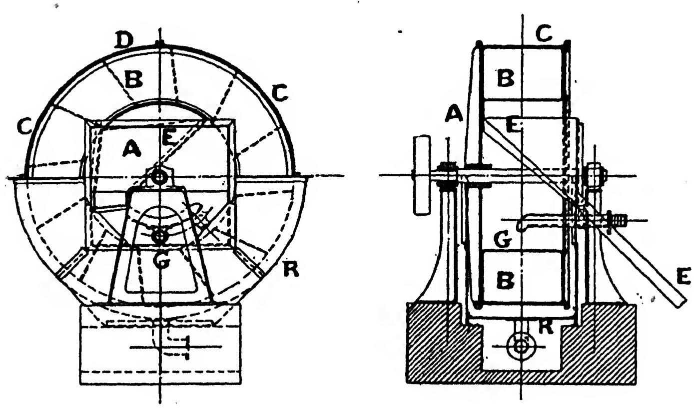


FIG. 39.—Revolving cane-juice strainer and cush-cush elevator combined.

division boards, or plates, B, are fixed, which act as elevators for the "cush-cush"; and the entire open periphery of the wheel is surrounded and enclosed by a very fine wire web, C, of the necessary width, through which the juice is strained. The latter is led by a gutter or pipe to the bottom of the slowly revolving wheel at G, and freely passes through the wire web, being collected in a small wheel race, R, and led to the pump by a second gutter. The "cush-cush," which is retained upon the inner surface of the strainer, is lifted by the angled plates, B, of the revolving wheel to the top of the latter, whence it falls at D by gravity into the hopper or shoot, E, which conveys it to any

required point. By this means all choking of the strainer is completely avoided, and a much finer straining medium can safely be employed than would otherwise be possible. The revolution of the wheel is continuously turning the inner surface of the strainer upside down, and, by virtue of

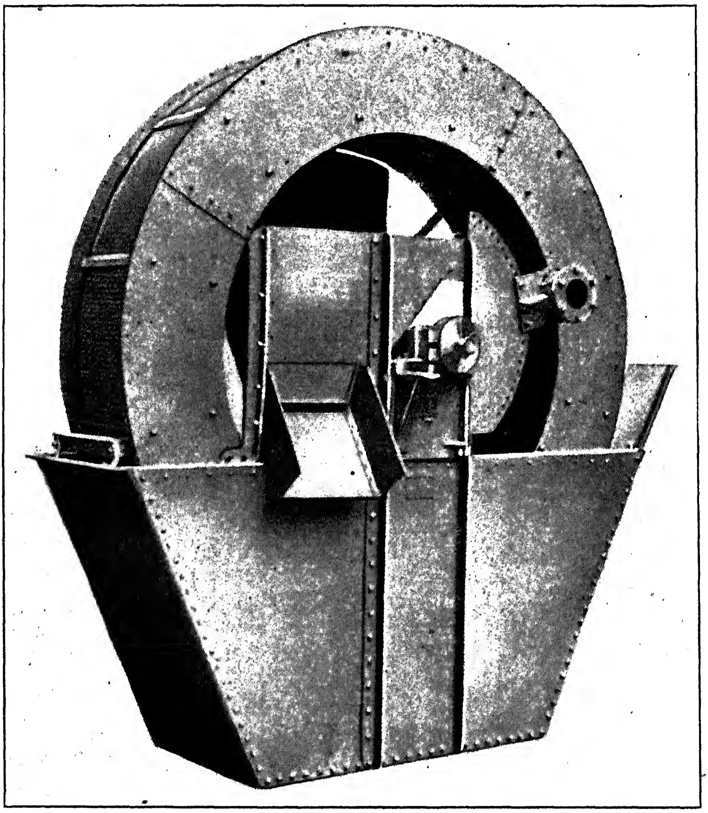


FIG. 40.—Revolving cane-juice strainer.

this reversal, relieves it from all obstructions to the free flow of juice without the baneful intervention of hand labour. Fitted with strong webbing, this apparatus will work smoothly and efficiently throughout an entire crop without any attention, securing for clarification a juice

as free as possible from mechanical impurities which are liable to impede and interfere with the work of the juice-heater and clarifiers. Fig. 41 shows the application of this combined strainer and elevator to a cane-mill, where it is fixed upon the outer end of the mill top-roller gudgeon.

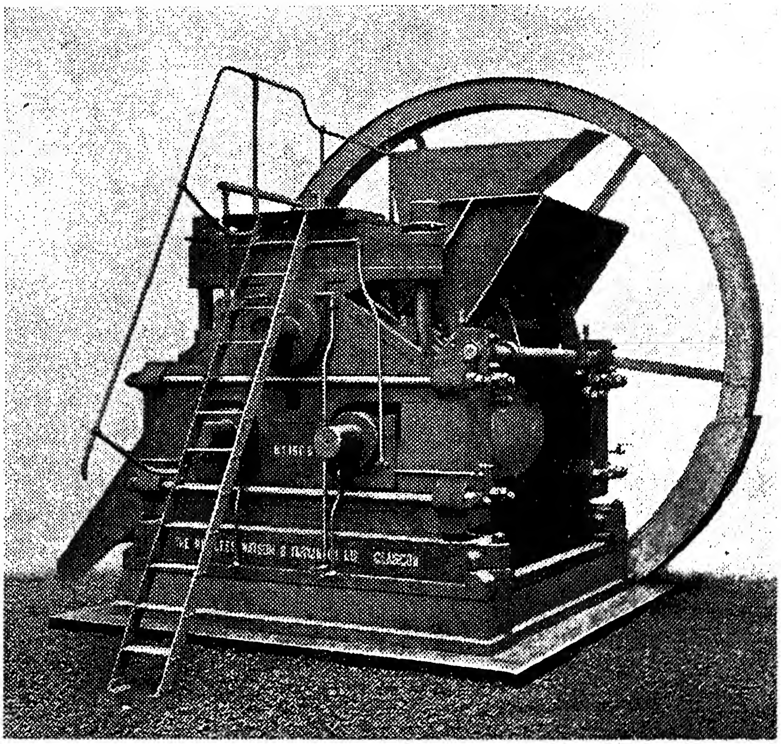


Fig. 41.—Revolving cane-juice strainer and cush-cush elevator combined, as fixed on the top-roller gudgeon of a three-roller cane-mill. The large wheel is the strainer.

Fig. 42 shows another interesting method of automatic straining, applied, in this instance, to a double-crushing plant. The expressed juice from both mills is delivered into the gutter A, and is discharged at the point B on to the curved strainer C, D, E. Suitable and light link-chain

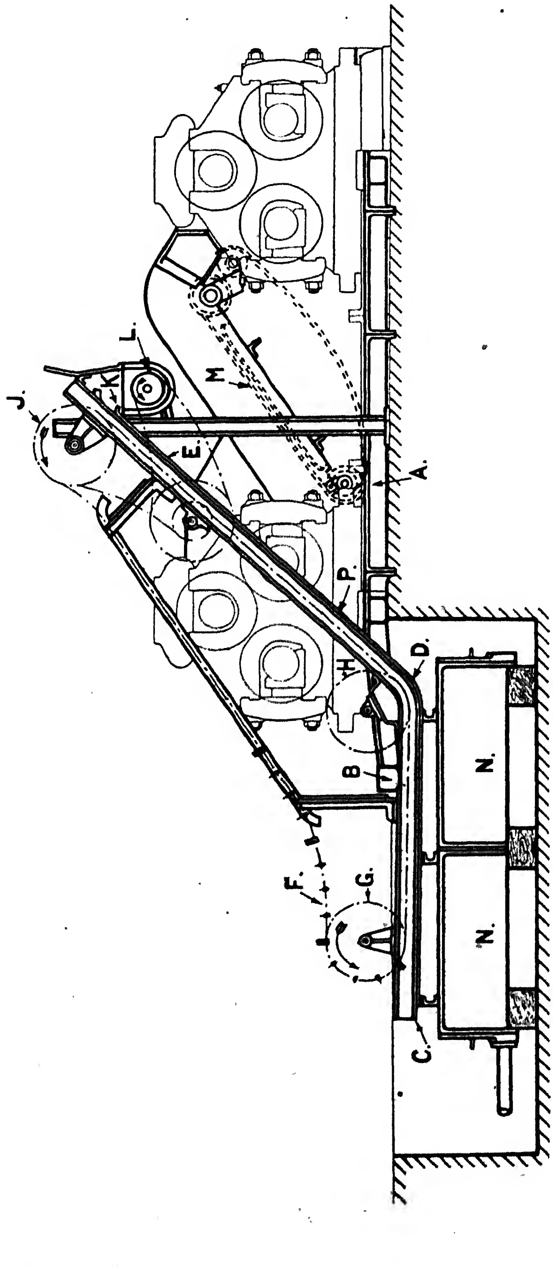
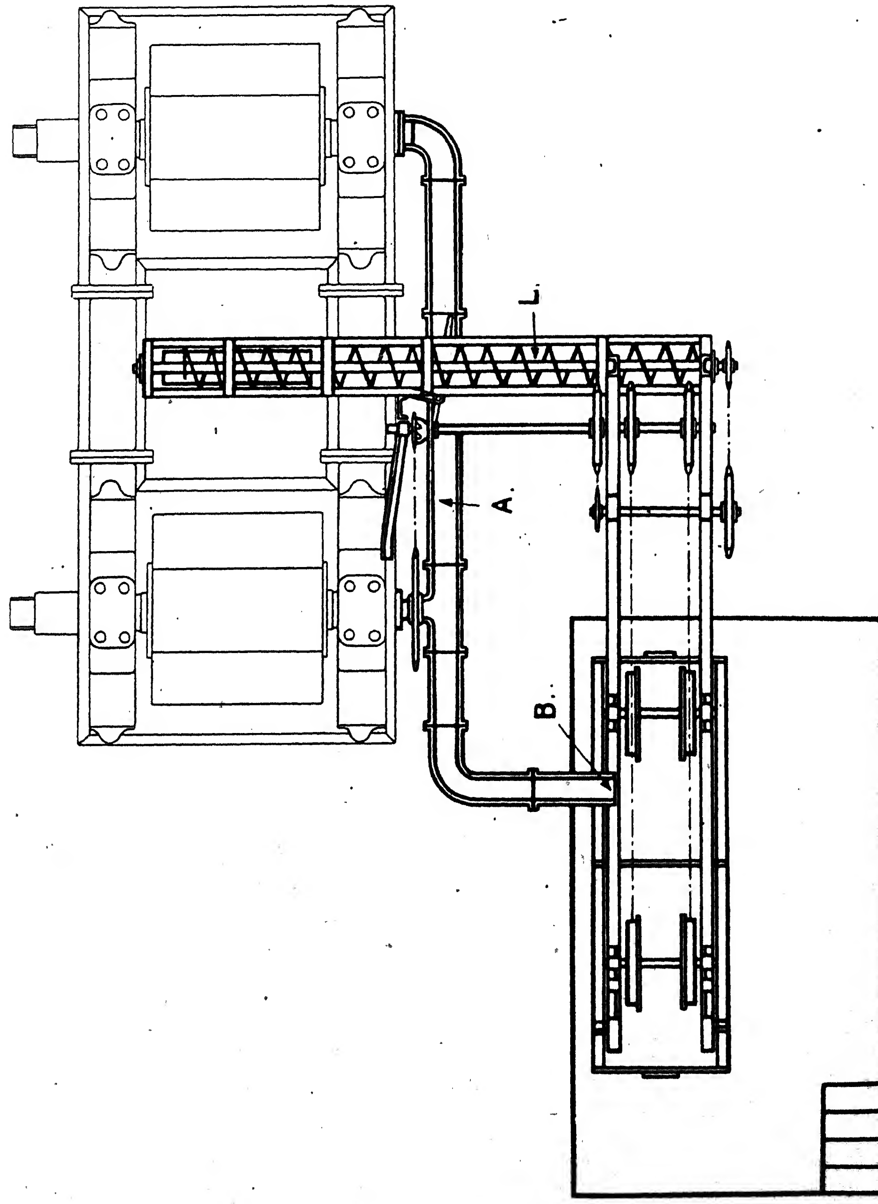


FIG. 42.—Cane-juice strainer and cush-cush elevator as applied to a six-roller cane-crushing plant.


L
A
B

belts, F, travel around the chain-wheels, G, H, and J, and to these chain-belts wood or iron scrapers, shod with rubber shoes, are attached. These scrapers travel over the surface of the strainer, and carry forward all the separated cush-cush over the plate P up to the point K, where it drops down the shoot L on to the intermediate carrier M, which

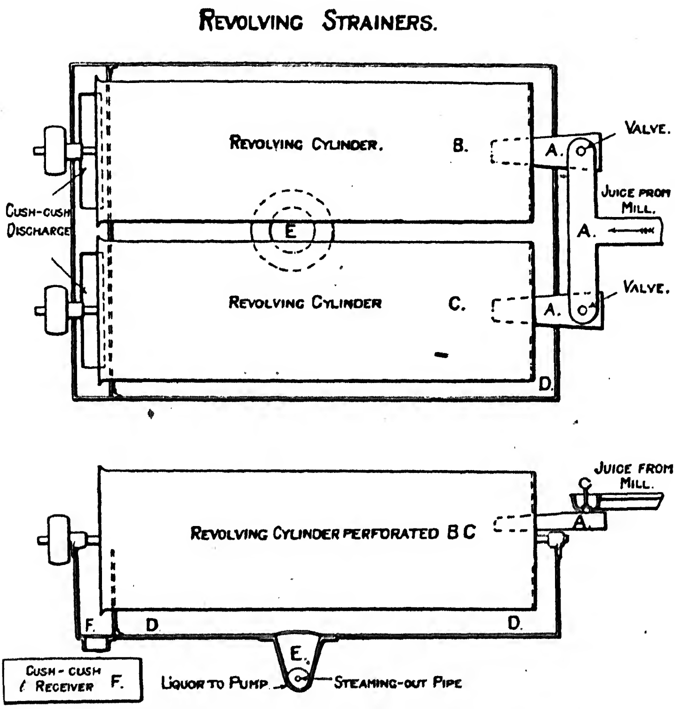


FIG. 43.—Revolving cylindrical cane-juice strainers.

conveys it to the rolls of the second mill to be squeezed again, in order that there may be no avoidable waste of juice. The bulk of the strained juice falls at once into the juice-collecting tank N, between the points C and D, whilst the remainder drains away between the points D and E, and is collected by the sloping gutter O, down which it runs

into the same tank, out of which all the collected juice is pumped to the clarifiers.

Fig. 43 shows a third method of automatic straining. The juice from the mill is conveyed by the gutter A to two revolving cylindrical strainers, B and C, through the cir-

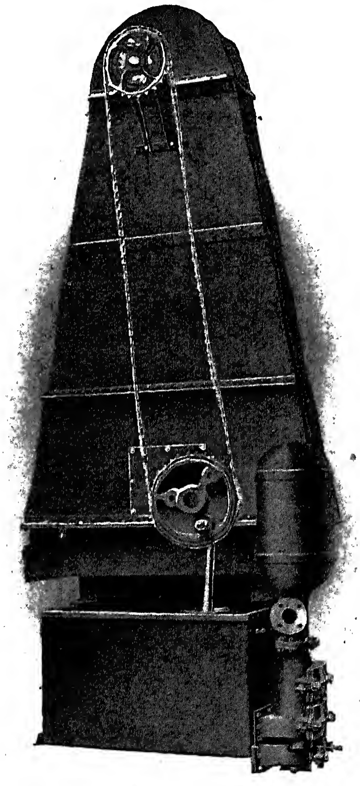


FIG. 44.—Strainer, elevator, and juice-pump combined.

cumferential surfaces of which the juice passes into the receiving tank, D. It is then collected at the point E, and led to the juice-pump, whilst the cush-cush travels along the entire length of the cylindrical strainers, and falls into the cush-cush receivers, F, from which it is removed by an elevator or by hand. Fig. 44 shows still another automatic

straining arrangement combined with the juice-pump and its tank, in which the moving parts of the elevator consist of a chain with attached paddles. The latter first drag the cush-cush, which has been separated from the bulk of the juice, over the strainer, and finally over a perforated plate, where further drainage takes place. Ultimately the residuals are elevated to a suitable height, whence they fall on to one of the mill-carriers to be passed again through some of the rolls, so as to minimise loss of juice in the refuse.

At the present time when such close attention is being paid to the attainment of maximum extraction, and in view of the largely increased quantities of cush-cush resulting from the action of an extended train of mills, coupled with the variation in the qualities and contents of the same coming from the respective mills, and even from the crusher, it has been found to be a matter of sufficient importance to subject the whole of the cush-cush from all of the strainers to the most thorough re-squeezing, and it is considered desirable to return the whole of it to the front of the first mill, in order that it may pass through the entire range of mills. Many disappointing figures *re* mill-work are due to neglect of this precaution, and their distinct improvement has been the result of its adoption.

Notice of cane-mill accessories has now, for the present, been completed, and the task of explaining the chief component portions of a simple form of cane-crushing machinery has also been finished. It is now necessary to pass on to a consideration of more complicated multiple arrangements of the latter, which aim at a more complete extraction of the juice from the canes than is possible by the use of one three-roller mill.

CHAPTER IV

MULTIPLE MILLS: THEIR WORK AND ARRANGEMENT

An endeavour must now be made to get somewhat farther beneath the surface of the subject which has been and is still being dealt with, in order that the true value of powerful cane-juice extractors may be the more clearly appreciated. It is well understood by planters that the ability of a cane-mill to express juice depends to a great extent upon the class of canes being dealt with, which varies considerably not merely in different countries, but also from time to time upon the same estate. It is therefore desirable that they should be able, as promptly as possible, to form a fairly reliable, even though only an approximate, estimate of the efficiency of the extraction of the juice from the canes that is being effected by any given three-roller mill, of any given style and variety of construction, when operating upon any given variety of canes, the terms "efficiency" and "percentage of extraction" denoting the proportion of the weight of the juice expressed by the mill to the original weight of the canes squeezed. In this connection special tests are one thing, and the careful daily supervision of the work of the mill another. Appearances are altogether misleading, and an attempt to judge the quality and efficiency of the cane-squeezing by an ocular and superficial examination of the megass is a futile amusement. Rollers of larger diameter and shorter length will give better results than those of comparatively greater length and lesser width, although the megass emerging from the wider and

comparatively shorter rollers does not, in some ways, always look as if it had been nearly so well crushed. Experience shows that rolls of small diameter usually break up and disintegrate the canes to a much greater extent than wider rolls do, and yet the actual squeeze administered, and its effects, are not always so productive of good results. Speaking generally, it would appear that fast-running mills give the best results, although the appearance of the megass does not lead to this conclusion, and, other things being equal, rolls of larger diameter may be said, to some extent, to give these improved results on account of their greater surface speed. Again, in making comparisons, it is very desirable to compare mills of differing sizes which are at work in the same factory upon the same class of canes. It is apt to be misleading, and it is comparatively useless, to compare the work of a small mill upon one estate with that of a larger mill in use in another factory, or vice versa, unless a very careful analysis of all the surroundings of the case in question is simultaneously made. This is a much more complicated and necessary proceeding than many people suppose, and it requires the efficient superintendence of a scientific expert who is capable of taking into consideration the comparative qualities of the canes manipulated in the respective factories, together with various other relative points which must not be overlooked. Taking the everyday work of a particular factory using a cane-mill with rolls of some 26 in. to 28 in. diameter by about 54 in. to 60 in. in length, running at a fairly slow surface speed, the average extraction effected by this machine over an entire crop is, say, 63 per cent. juice on the weight of the canes crushed. The megass left after obtaining this moderate result looks excellent. It is light in colour, well broken up, and, so far as mere appearance is concerned, would seem to indicate that the mill in question is doing extra good work. In this

connection it must, however, be carefully borne in mind that there are in existence fast-running mills of comparatively small size which, by virtue of their high roller surface speed and thinner feed, are actually doing specially good work. Alongside this small mill a larger crusher is erected, having rolls 34 in. in diameter by 72 in. long, and an average extraction of, say, 67 per cent. to 68 per cent. juice on the weight of a larger quantity of canes is effected. Nevertheless, the megass does not appear to be nearly so well broken up, and to a superficial observer does not seem to have received such an effective amount of treatment as formerly; and it is thus evident that a careful analysis of the megass must be made before a correct knowledge of results can be properly ascertained. This point will be more fully dealt with in due course, and will afford a very useful insight into the surroundings of this very important question, but it should here be mentioned that there is an evident inclination to hark back and reconsider the question of relative roller speeds, and in certain cases to reduce surface speeds.

In the everyday work of a sugar factory it is desirable that both the canes and the extracted juice should be regularly and continuously weighed—much useful information may be gained by this procedure; and if the weight of the canes themselves cannot be regularly ascertained, then the megass should be weighed. But if an intelligent and thoroughly efficient supervision of the mill's work is to be maintained, a mere comparison of these comparative weights is insufficient, and might lead to the erroneous conclusion that better crushing is being effected at certain times than is actually the case. Some canes are softer or more juicy than others, and more readily yield up a larger proportion of their contents to applied pressure, and although the yield of expressed juice seems to be more than usually abundant, the mill, contrary to inferences drawn

from insufficient figures, is not actually working up to standard efficiency. It is therefore at all times essential to note very particularly the percentages of fibre and moisture remaining in the megass (see Chapter X.), and to associate the figures so obtained with those ascertained through the weighing of the canes and juice. Thus, if with both soft and juicy or hard and drier canes the percentage of fibre in the resultant megass is carefully maintained at the same level in the case of all classes of cane-plants operated upon, it may usually be considered that the cane-mill is maintaining a fairly uniform level of practical efficiency under the varying conditions under which it is pretty certain to have to work at various periods of its employment. Again, in estimating the relative values and quantities of work done, such quantities should rather be referred to the percentage of fibre in the canes than to the total tonnage of canes dealt with by the mills.

Taking the above points into consideration, what average extraction of juice from the canes is to be expected through the use of an elementary cane-grinding plant, like the one already described and shown in Figs. 17 and 18? In answering this question, it should first be remarked that it is far too common a practice to work cane-mills much beyond their proper capacity. At the same time, this somewhat complex question of capacity must be considered in relation to the percentage of extraction which may be regarded as satisfactory in given cases; for with cheaply-purchased canes, or with very low sugar prices, it may pay to work with a comparatively lower extraction than would be regarded with favour under normal conditions. As a rule, an ordinary three-roller mill with canes containing 12 per cent. of fibre does not ensure an extraction of juice exceeding 62 per cent. to 65 per cent. on the weight of the canes. If the rolls run at a comparatively slow speed, and

are, say, of proportional sizes to rollers 32 in. in diameter by 72 in. in length, the lower extraction of 60 per cent. to 62 per cent. may be anticipated. If they are, however, constructed in the more compact ratio of 34 in. in diameter by 66 in. in length, the higher extraction of 65 per cent. may be looked for. The shorter rolls permit of a higher pressure per unit of crushing surface, and such increased pressure will be more perfectly maintained along their entire length; and modern mills are now usually constructed in accordance with these ascertained facts, thus promoting maximum efficiency.

Special tests conducted for brief periods are not being dealt with, but rather the average work of an entire crop; and in daily work it requires very careful and constant supervision to make sure of steadily maintaining the level of efficiency indicated on general lines in the foregoing figures. Taking, however, a rational mean of these, with the use of a good modern mill of adequate power and speed, fitted with relatively short rolls, a steady average of, say, 63 per cent. juice from any given weight of canes may be counted upon.

Searching more particularly into the details of this result, it is also ascertained that, in conjunction with this extraction, fully 24 per cent. of the total sugar that was originally contained in the canes under treatment is lost, this last percentage having been left in the megass which has gone to the furnaces. The amount of sugar extracted from the canes does not, of course, coincide precisely and proportionately with the amount of juice extracted. Taking the particular sample of canes which is now being referred to as containing by weight some 12 per cent. fibre and 88 per cent. juice, the latter, upon analysis, would be found to contain fully 14 per cent. sugar, associated with some 2·5 per cent. other solids, and 71·5 per cent. water, on

the weight of the canes. Taking 100 parts of this juice, it is found, in round numbers, that it is chiefly composed of about 16 per cent. sugar and 84 per cent. water. For the present, it is desirable to refrain from going too precisely into these figures, lest attention should be drawn away from the main generalities under consideration, and it need only be repeated that there is an approximate loss of some 24 per cent. of the total sugar in the canes, which would be left in the megass after good average crushing with a mill of this description.

In dealing with the question of extraction, so far as it concerns old and comparatively weak mills working in old established factories, it is desirable to emphasize the chief considerations at issue which, if possible, are in general cases to avoid as much as possible any undue waste of power in an excessive pulverisation of the cane-fibre, yet nevertheless to obtain the maximum extraction of sucrose when desired. The coarser the megass the better the resultant quality of the furnace fuel so obtained, provided always that the final megass is sufficiently dry. Very finely crushed megass is a somewhat troublesome class of fuel to deal with in the furnaces, much more so than well-dried single-crushed megass, and so long as the required degree of extraction of sucrose is secured, it is desirable, as much as possible, to avoid an undue expenditure of engine-power in an unnecessary application of excessive pressures to the woody matter of the canes. Comparatively speaking, remarkable results have been obtained through judicious control and wise manipulation exercised over the use of old and weak mills, clearly demonstrating the importance of not relying on brute force more than is absolutely necessary.

An effort must now be made to explain how a higher and better extraction can be judiciously ensured by those

desiring it, and to call attention to the very interesting and efficient appliances available for this purpose. Individual planters can then be left to decide under the surrounding circumstances of their particular cases, coupled with special reference to the relative prices of both canes and sugar, whether the more complete and powerful multiple mills will pay for their increased first cost and greater working expenses by their increased results.

In the latter half of the last century, when close attention began to be paid to this question of increased extraction, a second mill was frequently erected in a convenient position, side by side with the first and original crusher, somewhat as shown in Fig. 45. Here, A is the first mill, and B the second. A is driven by its own separate engine C, and gearing D; and B is similarly driven by its own separate engine E, and gearing F. Each mill has its own cane-carrier; the first at G, and the second at H, R. Under normal working conditions, the cane punts or trucks (which have brought the canes from the fields) surround the first cane-carrier, G, as shown at J, and the canes, having been placed upon G, are conveyed to the mill A. Passing through the rolls of this first mill they emerge in the form of single-crushed megass, relieved of a large proportion of the total juice they originally contained, and, passing down the megass-plate at K, they are deposited upon the narrow and quickly-moving megass carrier at L, which in turn leads away the megass and deposits it upon the diagonal conveyer M. The latter then conveys the megass and drops it upon the second cane-carrier, H, where it is spread and carried forward to the second mill, B. Emerging from B at the point N in the form of double-crushed megass, it slides down the megass-plate on to the next cross-carrier, O, which puts it into the curved shoot P, where it falls on to Q, the last of the mill-carriers, and is conveyed to the

furnaces. The whole system of the four carriers, L, M, O, and Q is arranged to be driven by either of the mills, and can be each and all thrown out of or into gear at a moment's notice, so that whichever of the mills happens to be at work the service of the requisite conveyers is always at command. The final carrier, Q, takes the place of the megass elevators (one to each mill), which would otherwise be in evidence; and thus there is a complete system which is serviceable either for single-crushing by either mill, or double-crushing through the joint action of both mills. When the second mill has to crush singly, the punts or trucks surround the second cane-carrier at R, and both sections, H and R, of this carrier are, at all times, waiting in readiness to act in conjunction, and so serve the second mill when operating as a single-crusher, and the small shoots at P are arranged to suit either system. The object of the above arrangement of mills and carriers is to make provision in case of accidents. If the first mill A broke one of its rollers, then the second mill B could continue at work with its own cane-carrier and its share of megass-conveyers, and the manufacture of sugar could be continued in connection with the single-crushing of the canes, in place of double-squeezing. So, too, if the second mill broke a headstock, the first mill would continue working, and could get rid of its single-crushed megass direct to the boiler furnaces, instead of first sending it to the second mill via the extra cross-carriers.

By means of this arrangement of the mills, the work of the factory was certainly, in one way, uninterrupted, and the canes already cut down in the fields could be promptly disposed of; but, on the other hand, this convenience was purchased by some reduction in the day's work, by some increase in the fuel account, and the loss of the extra sugar which would have been secured through the use of two mills in place of one. Owing, however, to the increased

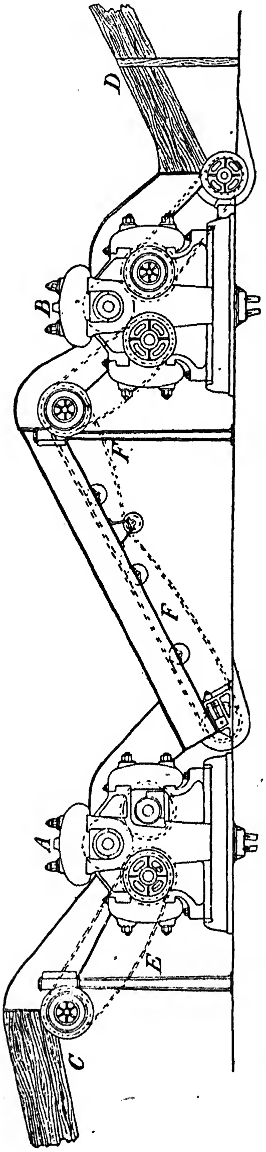


Fig. 46.—Elevation of tandem double-crushing plant, each mill being worked by its own separate engine.

strength of modern milling plants, frequent breakages are nowadays not expected to happen, except through carelessness and inattention, or other causes which can be guarded against in better ways than saddling an estate with cumbersome and somewhat antiquated and unsatisfactory arrangements. Certain spare pieces of the parts of the machinery, most likely to fail, can be kept ready at hand, together with efficient standing appliances for rapidly effecting repairs; and the possibility of now being able to command these conveniences, coupled with a feeling of unwillingness to lose even a fraction of maximum advantage in these days of keen competition, has gradually led to the placing of multiple mills in "tandem" positions, instead of side by side. In place of the arrangement just described, they are therefore frequently arranged somewhat as shown in Figs. 46, 47, and 48. In this more modern arrangement each mill still has its own separate engine and gearing, plus minor and special accessories, but there is only one cane-carrier and one megass-elevator common to the two mills,

and no attempt to single-crush would be contemplated. The first mill is at A (Figs. 46 and 47), the second at B. The gearing and engine of the first mill are shown at G and H, whilst those of the second mill are to be seen at J and K. The cane-carrier is at C, and the megass-elevator at D. The method of driving the cane-carrier is shown at E, the megass-elevator being driven in a similar manner; and the intermediate carrier and its driving gear are shown at F, together with various other minor details of interest, and this simpler form of intermediate carrier takes the place of

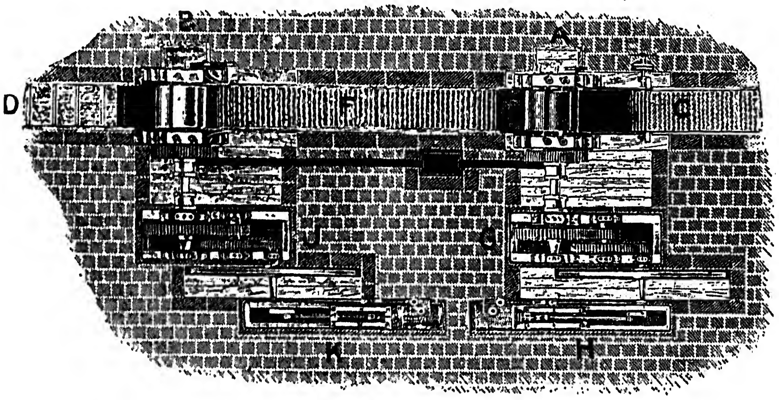


FIG. 47.—Plan of tandem double-crushing plant shown in the preceding illustration.

the complicated arrangement of the more numerous conveyers in Fig. 45. Turning to Fig. 48, a full perspective view of the *tout ensemble* of such an arrangement of mills is shown, together with a fine pair of cane engines. The two sets of gearing are seen close behind their respective engines, and although the mills are somewhat hidden away to the rear it will be noticed that they are both fitted with toggle gear, and that they are preceded by a Krajewski crusher, which appears in the far-away top corner of the illustration. Fig. 49 is a separate view of the first mill of this double-crushing plant, and is a good example of a

modern cane-mill fitted with the two accessories just mentioned, the second mill being a precise duplicate of this, minus the crusher.

The next step was, while still placing both mills in tandem position, to keep them closer together, and fix their beds or bottom castings upon the same gantry as shown in Figs. 50, 53, and 54. This more compact arrangement enables the two mills to be worked by the same engine and gearing, thus giving complete control over the relative roller

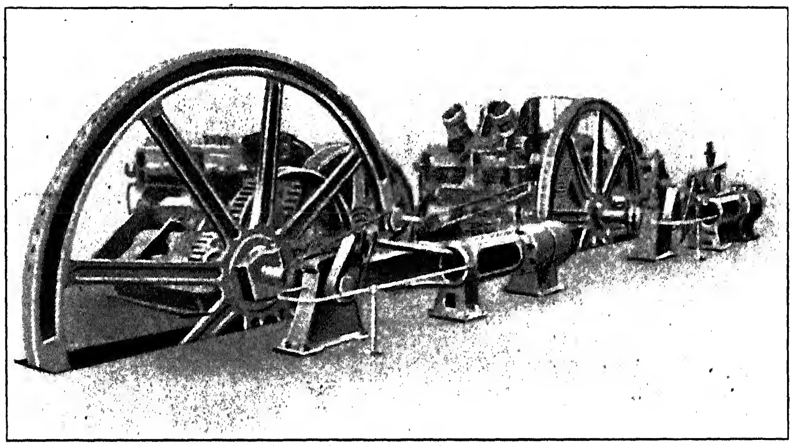


FIG. 48.—General perspective view of tandem double-crushing plant similar to those shown in the two preceding illustrations.

speeds of the respective mills. The engine has approximately to have twice the power necessary for one mill; and the gearing has correspondingly to be increased in strength, and it is sometimes extended by an additional first- and second-motion spur-wheel and shaft. In such case the first-motion pinion, A, has to work both the first-motion wheels, B and C (Fig. 51). There are likewise two tail-bars, D, transmitting the power and motion to the respective mills. Alternative arrangements of this double gearing are used; and there is often only one first-motion wheel and

shaft, in which case there is also but one second-motion pinion, which drives both the second-motion wheels, as in Figs. 50 and 52. The cane-carrier is shown (Fig. 51) at E, and the megass-elevator at F; and when the single-crushed megass leaves the first mill, K, it is deposited with as little disturbance as possible upon the intermediate carrier, L,

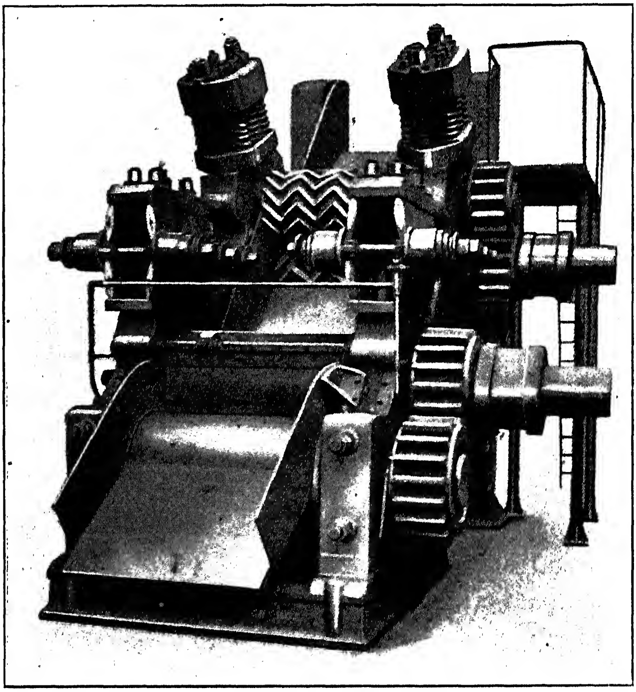


Fig. 49.—The first mill of the tandem double-crushing plant.

which is of light though strong construction, and travels at about the same lineal speed as the surfaces of the first mill's rollers. The surface speed, however, of the rolls of the second mill is usually rather higher than that of the first. Thus, if the roller surfaces of the first mill travel at the rate of, say, twenty feet per minute, those of the second will revolve at the rate of about twenty-three feet per minute,

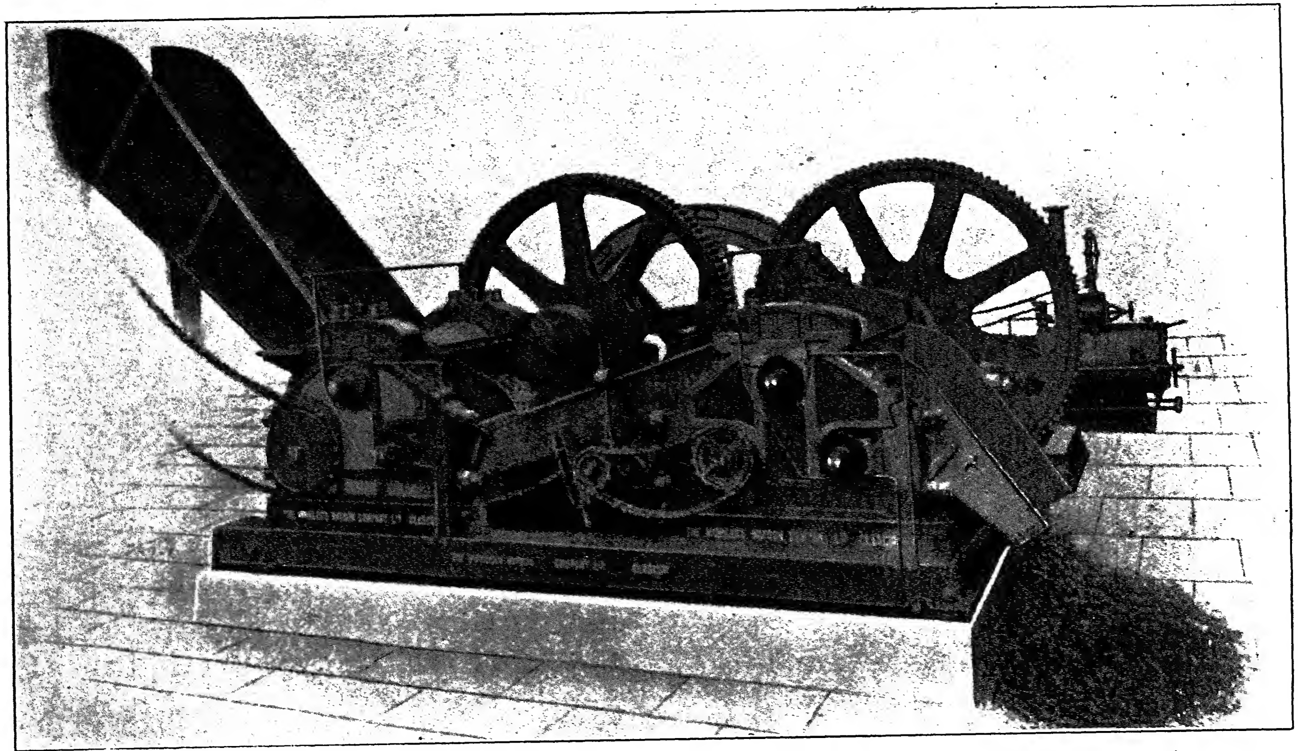


FIG. 50.—General view of tandem double-crushing plant mounted on the same bed-plate, and worked by one engine.

these proportional speeds being arranged with a view to minimise the chances of choking the second mill. Again, in some countries the converse of this practice is adopted, presumably with a view to ensure a more severe final squeeze than might otherwise result.

Fig. 50 shows a very simple yet sound example of a compact arrangement of a double-crushing plant of this description, which though dispensing with certain accessories described in a previous chapter, nevertheless affords,

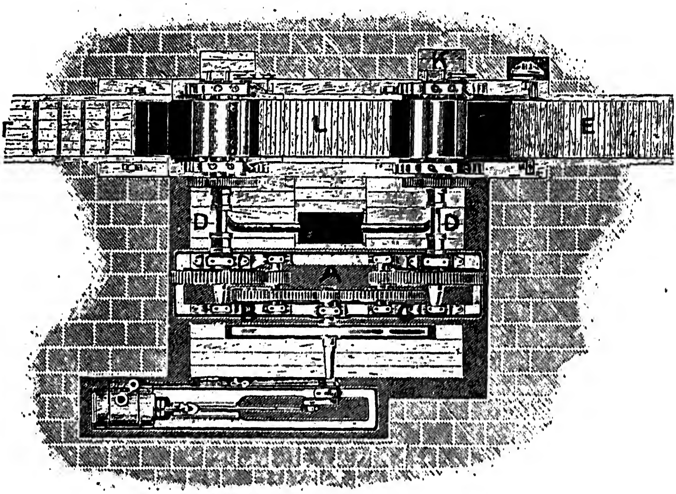


Fig. 51.—Plan of a tandem double-crushing plant worked by one engine.

with due care and attention, full opportunity of securing such advantages as may be obtained by the employment of two mills in place of one. Figs. 52 and 55 are striking perspective views of the engines and more complicated gearing characteristic of such a combination of double mills, and they give an interesting idea of the increased strength of both these elements, which, in cases of this class, have to be increased greatly in size and relative power to enable them to cope with the double duty which they have now to perform.

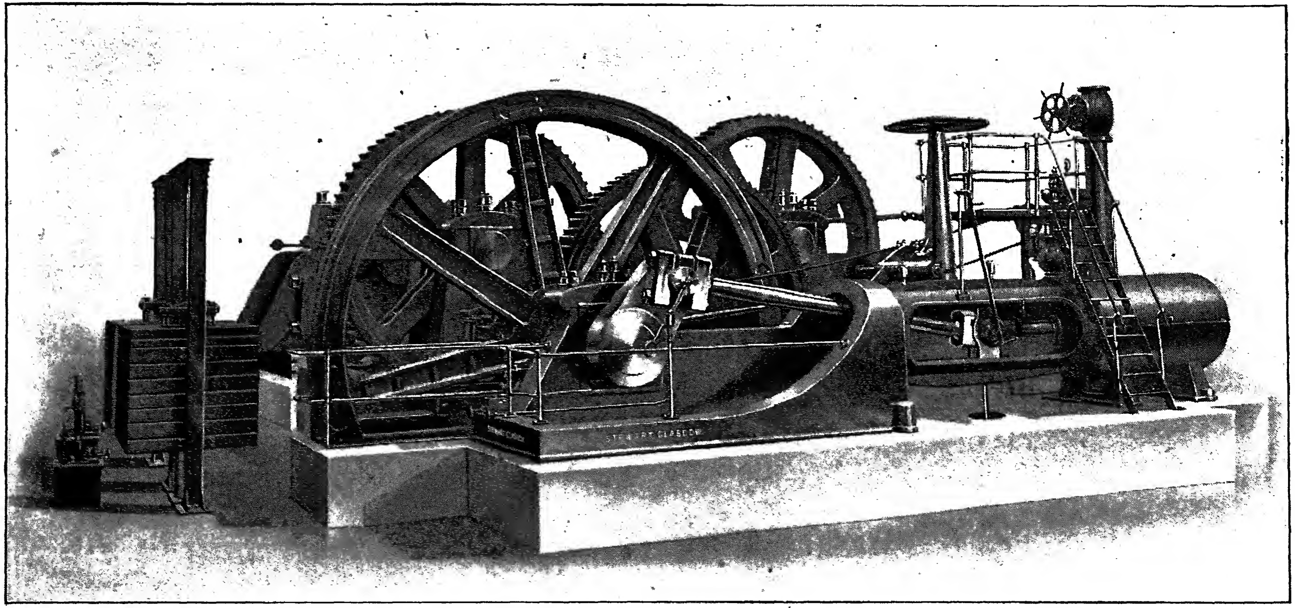


FIG. 52.—General perspective view of tandem double-crushing plant, showing engine and gearing.

The next question to be considered is the comparative general efficiency of these arrangements and their respective advantages. Premising that the exact form and disposal

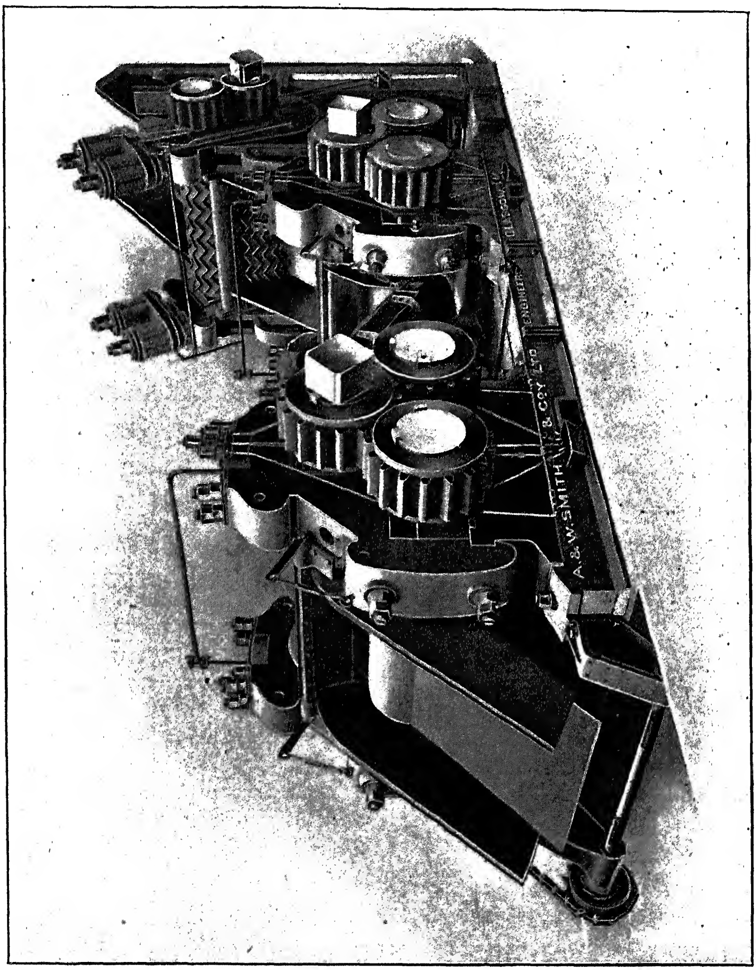


FIG. 53.—General view of tandem double-crushing plant, with Krajewski crusher and special arrangement of combined mill-beds and gantry.

of the double-crushing plant to be adopted must be determined by the requirements of each particular case (which may be either to crush more cane in a given time without

regard to the question of extraction, or to obtain a higher extraction from the original weight of canes, or to divide these advantages and obtain something of both), it will for the moment be assumed that the two mills are working as dry double-crushers pure and simple. The increased advantages to be gained by this increased effort to obtain increased extraction will be considered, and reference will be made to the older and earlier arrangement of the mills as shown in Fig. 45.

Let it be taken for granted that the entire combination of the two mills in this illustration is in full and uninterrupted operation. Then an extraction of at least 70 per cent. normal juice on the weight of the canes ought to be obtained, as compared with the 63 per cent. obtained by the use of a single mill, or an increased extraction of some 10 per cent. normal juice, the loss of sugar left in the megass being likewise reduced from 24 per cent. to 17 per cent. of the total sugar in the cane.

The full working advantages do not, however, end here; for, whilst both mills are at work, a certain number of steam-boilers are used to furnish steam to drive the machinery and supply the other steam-requirements of the entire factory. They are probably all being fired with the refuse cane or megass, without the assistance of any coal or wood fuel. Let it be supposed, however, that one coal or wood-fired boiler is also in use to equalise the fluctuating supply of megass from the mills, and to render it feasible to store a moderate quantity of reserve megass, and to ensure the uniform working of the factory. All is working well and satisfactorily. Suddenly an accident happens to the second mill, B, and it is decided to continue the work of the factory by means of single-crushing performed by the remaining first mill, A. As all the appliances and necessary arrangements are available, purposely waiting in

readiness for a prompt resort to the simpler and less efficient form of extraction, there is, therefore, nothing to prevent an immediate change. It might be supposed that the disadvantages would be confined to the loss in the megass of the extra 10 per cent. juice which would have been further extracted by the second mill, were it working as usual, coupled with some reduction in the bigger day's work that would otherwise be performed. But this is not so. Upon proceeding with the reduced work of the factory,

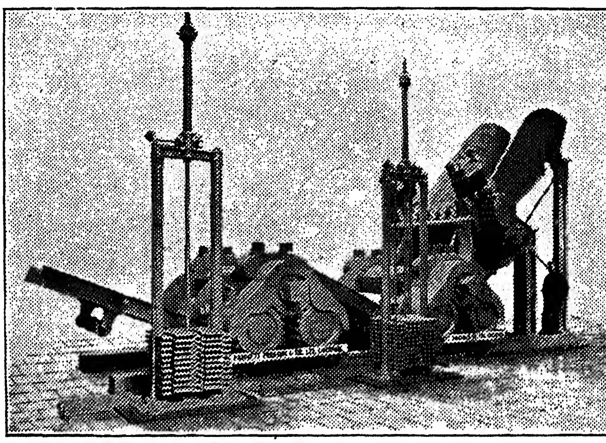


FIG. 54.—General view of tandem double-crushing plant, showing another special method of mounting the two mills.

it will soon be apparent that it is absolutely necessary either to fire up another coal or wood-fired boiler, or to force the one already in use. That is to say, until the second mill is repaired and resumes its duties, not only is a less day's work being done and less juice being extracted from the canes; but more coal, wood, or megass is being burnt to manufacture this reduced quantity of juice into sugar. Even making certain allowances for the larger quantity of sugar contained in the reduced quantity of megass coming from the single mill, and for the reduced

quantity of juice which has to be made into sugar, the very important conclusion is arrived at that, with double dry-crushing, one of the chief functions of the second mill is that of a fuel saver and improver, in addition to its duty as an extra juice extractor. Circumstances may modify particular cases, and it must not be forgotten that the factory may now temporarily be larger than necessary for dealing with the reduced quantities of canes and resultant juice, an important point which would in itself account to some extent for some of the extra fuel now required. But the broad fact remains that, owing to the loss of the use of the second mill, the resultant efficiency of the available megass fuel is impaired, and it becomes necessary to supplement it by the use of additional coal or wood, or by drawing upon the reserve stock of surplus megass which may have been stored for emergencies or for finishing off the manufacture of second-sugars and rum at the close of the crop.

The quantity of moisture left in the megass after effective double dry-squeezing may be put at about 50 per cent. on the total weight of the megass, whilst with single squeezing this figure may rise to over or about 55 per cent. This objectionable increase is accountable for the inferiority of single-crushed megass as fuel when compared weight for weight with that left after dry double treatment, for, other conditions being equal, the drier the megass the more valuable are its steam-raising properties.

The realisation of these facts leads to a due appreciation of the more modern arrangement of the disposal of the two mills, as shown in the accompanying illustrations. To some extent it also explains why planters are content to forgo some of the conveniences afforded by the older arrangements, and are now giving preference to the compacter forms of tandem mills, which virtually tie them down to multiple-crushing, without an alternative. It further

leads up to the explanation of another improvement which may be effected in the duty performed by the second mill as an extractor; for supposing that a supply of megass fuel of extra dry quality is a secondary consideration, the total extraction due to double-crushing may be appreciably increased by adding boiling water to the megass at the moment it issues from the rolls of the first mill. Such an addition of hot water, equal to, say, 10 per cent. on the weight of the juice extracted by this mill, should result in an approximate total extraction due to both mills (as arranged in Fig. 50) of 86 per cent. of the total sugar in the canes crushed. This treatment reduces the loss of sugar in the megass from 24 per cent. with single-crushing, or 17 per cent. with dry double-crushing, to 14 per cent. with double-crushing and imbibition combined. If a preliminary crusher is also employed, as in Figs. 53 and 54, the extraction, with imbibition, will be raised to about 88 per cent., and the loss reduced to 12 per cent.; whereas if dry-crushing were prosecuted with such a combination of mills and crusher, the total extraction would be about 85 per cent., and the loss of sugar 15 per cent. With reference to the fuel question in connection with imbibition or maceration, the increased temperature of the resultant megass fuel will to some extent compensate for its increased moisture.

In addition to these considerations, it has to be remembered that if any mill of a given size is employed for the purposes of single-crushing on any estate, and a duplicate second mill is erected to work in conjunction with it, so as to effect double instead of single-crushing, then not only will the above increases in juice extraction be effected, but also about 30 per cent. increase in the total day's work. If, however, in place of one additional mill an entirely new plant of modern double mills is ordered and the old mill is discarded, then the size of each of the two new mills would

only require to be about two-thirds the size of the latter in order to give the foregoing degrees of extraction, and at the same time cope with the original weight of canes which was being dealt with by the old mill.

Before leaving, for the present, the question of double mills, it will not be out of place to consider a special phase of double-crushing which might be instituted by installing a Krajewski crusher in front of a single mill, as shown in Figs. 34 and 35. Cases may arise in which the addition of a two-roller crusher may be preferred to the purchase of a second three-roller mill, and it has then to be decided what degree of extraction may be anticipated. The Krajewski crusher is itself capable of effecting an extraction of, say, 50 per cent. of the total juice of the canes; and, estimating the extraction of a single mill at 63 per cent. as before, it is found that by installing the crusher the total extraction can then be increased to some 67 per cent. of the normal juice on the original weight of the canes worked, coupled with an increase of, say, 20 per cent. to 30 per cent. in the original day's work, and a much more uniform and smooth working of the old three-roller mill is likewise ensured. By this means some 80 per cent. of the total sugar in the canes is obtained, coupled with a loss of about 20 per cent. sugar in the megass. Imbibition could not, however, be very usefully attempted with such an installation, and dry-crushing would have to be the order of the day until a following mill could be installed; and Figs. 53 and 54 show two interesting examples of modern arrangements of double-squeezing mills with a crusher in front of them, in conjunction with which imbibition could usefully be employed. In Figs. 50 and 53 it will be noticed that the two mill-beds and the customary gantry are combined in the one and the same massive casting, whilst in Fig. 54 the mills are furnished with double hydraulic accumulators, and

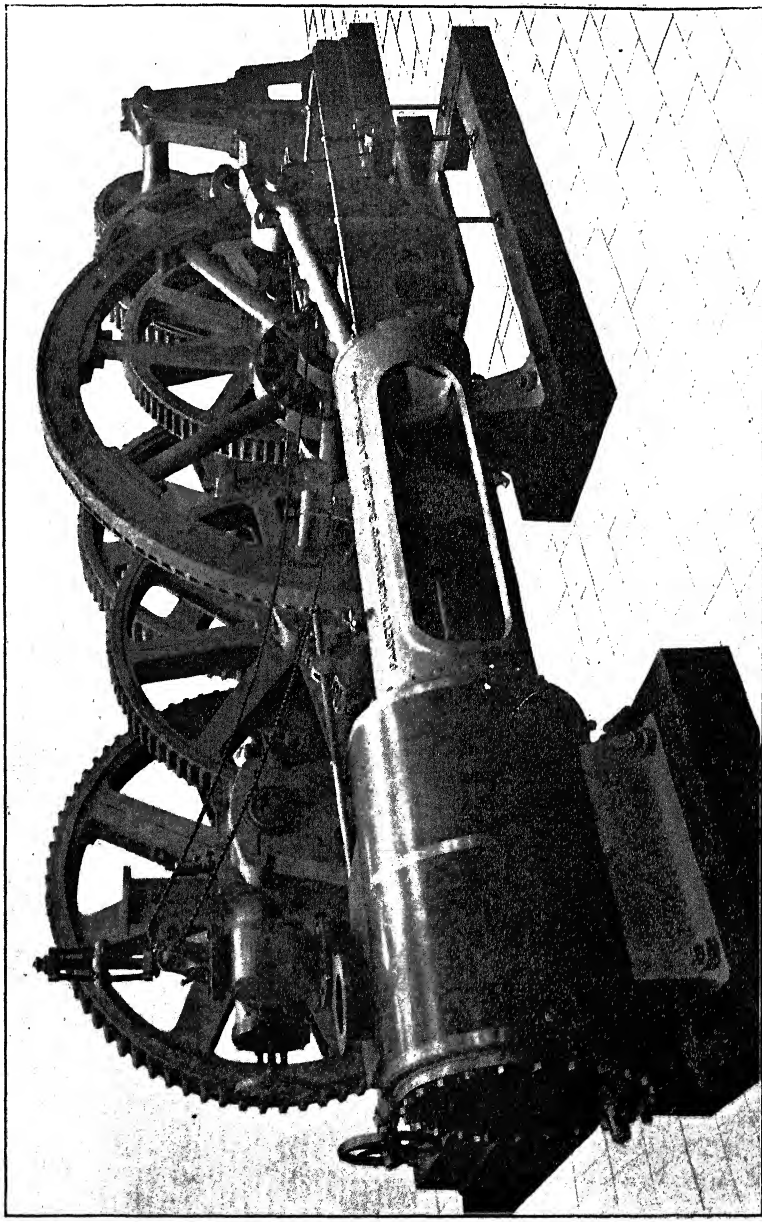


FIG. 55.—Engine and gearing for driving the plant shown in the preceding illustration.

are mounted in a distinctive and characteristic manner which should be noted as a matter of general interest.

With reference to the question of "imbibition" or "maceration," which bears upon the addition of a greater or lesser quantity of water to the megass on its way from an earlier to a succeeding mill, it should be remembered that megass is of a very spongy nature, and possesses somewhat unsuspected or unrealised properties of absorption. It is also well to administer the addition of the water the moment the megass emerges from the rollers and is expanding; but this is a subject which will be more fully dealt with in connection with the description of the various methods used for ensuring a satisfactory absorption up to the point of saturation.

The general adoption of double mills was not accepted as a matter of course. Their introduction, as in the case of most innovations, was the subject of much controversy and analysis; and the change from single to double-crushing assumed the form of a gradual devolution. In the West Indies, up to this period, a noticeable difference was observable in certain cases in the methods of extraction respectively practised in French and British colonies. The former, encouraged by substantial protection and the consequently higher prices obtainable for their finished products, were tempted to carry the process of extraction of sugar from the canes to the farthest point practicable, and frequently employed the diffusion process for this purpose. The latter, unaided by bounties and protection in any form whatever, being left to fight their own battle in an unprotected and somewhat adverse and uncertain market, ruled by competitive and falling prices, were very cautious about adopting multiple mills and increased extraction. Diffusion, with its complexities, was regarded with much suspicion and disfavour; and after the estab-

lishment of five-roller (Fig. 30) and double mills (Fig. 45), it is probable that, but for continental influences, further advances in the progress of increased extraction and the introduction of tandem plants would for some considerable time have remained in abeyance.

German sugar engineers, acting in unison with their nation's rapid commercial expansion, and the consequent search for colonial markets, made special efforts to intro duce the diffusion process into British colonies, whilst French engineers also made similar exertions in various parts of the world. In this direction both parties were so far successful, that they induced the prosecution of numerous and fairly exhaustive experiments in widely divergent countries with reference to the application of this process to the cane-sugar industry; and up to the autumn of 1890 there seemed to be every probability that diffusion would take up a permanent position as an available and practicable cane-sugar extractor. Thus the supremacy of cane-milling plants was threatened, and the makers of such machinery made earnest endeavours to render their appliances as efficacious as a diffusion battery; and the struggle between "force" on the one hand versus the natural law of osmosis on the other, has, for the present at any rate, left the makers of cane-mills practically in possession of the field. To show how this result has been obtained, it is necessary to pass on from the consideration of single and double milling plants to that of treble and quadruple installations.

At this stage it will be useful to note the following figures, which show concisely the approximately relative positions of the various methods of extraction in vogue at this period. They also give some idea of the magnitude of the task which lay in front of the makers of multiple milling plants, and later on it will be seen to what extent the efforts made have been justified. Taking into consideration a

similar class of canes to those already alluded to in foregoing figures, the following results are shown:—

	Percentage of Sugar obtained on Total Sugar in Canes.	*Percentage of Sugar lost in the Megass on Total Sugar in Canes.*
Single milling	76·00	24·00
Double milling (dry) ..	83·00	17·00
,, ,, (wet) ..	86·00	14·00
Diffusion	96·00	4·00

It is seen that the gap between the results obtained by the better class of work done by double mills on the one hand, and diffusion on the other, permits of the possible attainment of an increased extraction through the agency of mills of 11 per cent. to 12 per cent. more sugar than had hitherto been obtained by the use of the double installations so far described. As a matter of actual fact there was, at this particular period, frequently a margin of 18 per cent. in favour of diffusion, where dry double-milling was concerned, and it was on the basis of this wider margin that the West Indian diffusion experiments were first instituted.

In order to obtain the more advanced results which were requisite to justify the continued use of mills when exhaustive work was to be done, the various machinery makers unanimously followed the somewhat obvious course of increasing the number of mills simultaneously and successively employed in crushing the canes under treatment. Thus, as already described, for a moderate degree of extraction, one three-roller mill can be used as in Figs. 56 and 57. For an increased extraction of some 10 per cent. two similar machines have been employed, as in Fig. 58; and now for further increases in obtained results, three, four, and even five three-roller mills are simultaneously and successively employed as consecutive units in the same

train of the cane-crushing plant, assisted by various effective accessories—such as cane knives, crushers, and

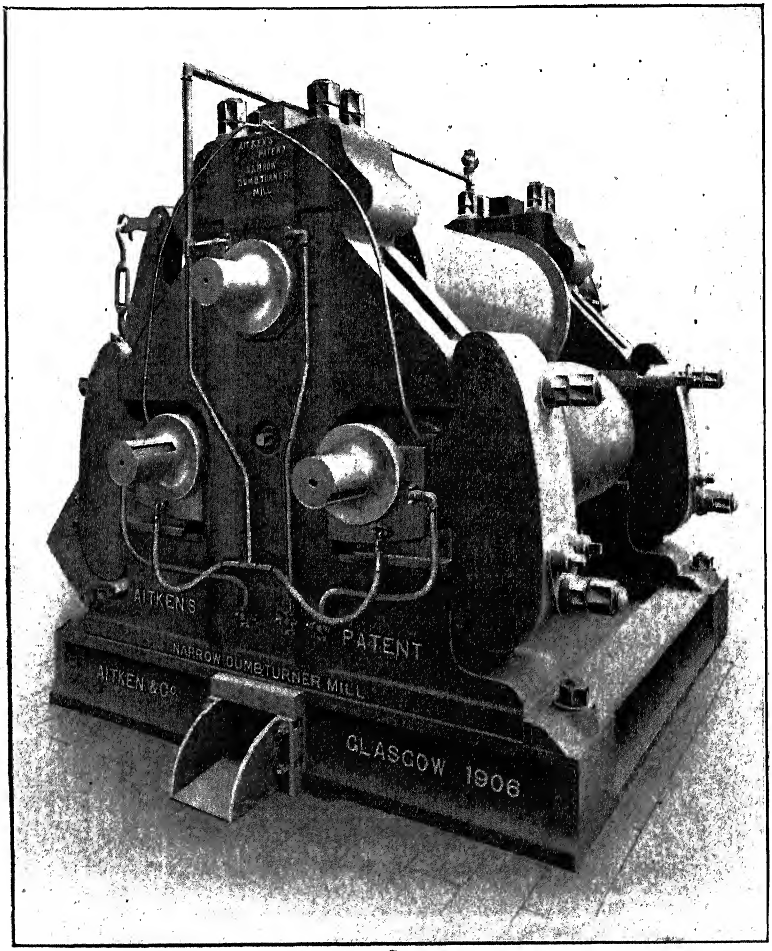


FIG. 56.—Perspective view of a single three-roller cane-mill of special design, showing the water-service pipes for cooling the mill journal brasses.

shredders—which have for their objective point the exhaustion of the canes of saccharine matter up to any feasible degree desired.

Figs. 59 and 61 show how any three such mills are usually arranged so as to form a simple nine-roller plant, in which A, B, and C are respectively the first, second, and third mills mounted in tandem positions on the same

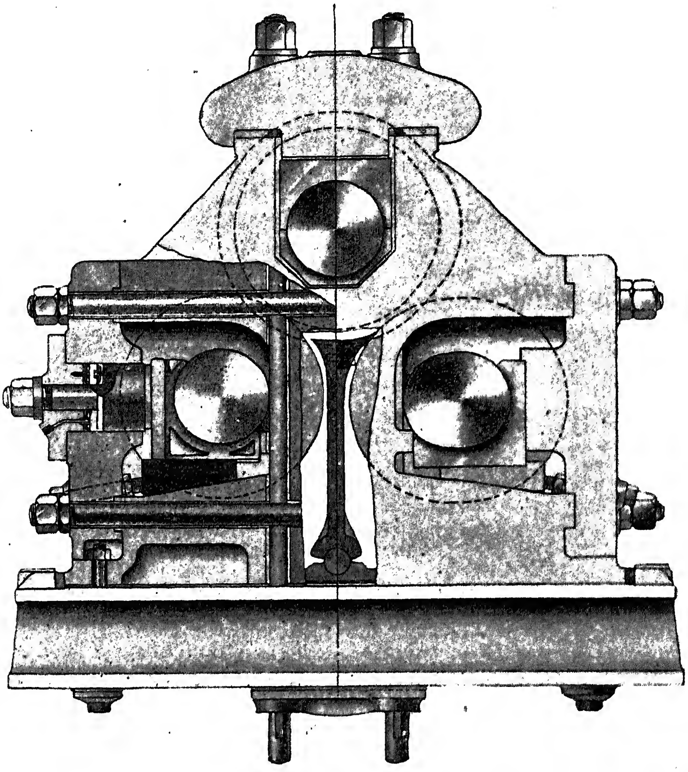


FIG. 57.—Sectional elevation of a cane-mill similar to that shown in illustration No. 56, showing the application of hydraulic pressure to the megass roller; also the special method of adjusting the bottom rollers in connection with the use of a very narrow trash turner.

massive mill-bed, D. The canes enter the mill at E, and after undergoing eight successive squeezes, emerge from the third mill at F in the form of "triple-crushed" megass. The mills are all worked under hydraulic pressure, each machine being furnished with its own accumulator and

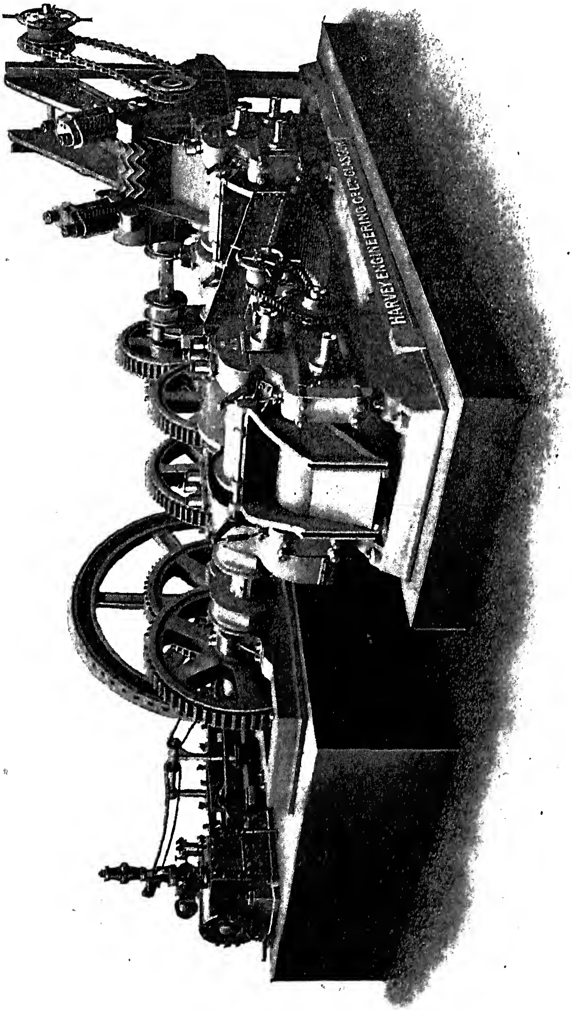


Fig. 58.—A six-roller mill with Krajewski crusher.

force-pump, as seen at G, H, and I; and it will also be noticed that this pressure is applied only to the top roller

of each mill. Furthermore, it should be noted that in multiple installations of this description toggle and hydraulic apparatus are virtually indispensable, or at least very desirable, and they therefore practically cease to be mere accessories. Hitherto, in describing the application of toggle gear or hydraulic pressure to cane-mills, the functions of such appliances have been dealt with in reference to their usefulness in protecting a single mill from sudden shocks and strains when it is worked by its own engine, the maximum power of which the mill is fully qualified to withstand under normal conditions. When, however, a series of two or more mills is driven by one engine, the power of that engine must be fully sufficient to drive simultaneously all of the associated mills when dealing with a full feed of canes; and it is quite within the range of possibilities that this multiple power might at any moment become concentrated upon any one mill of the series. An extra, and hitherto unusual, duty is thus thrown upon the above apparatus, and its usefulness is extended as an ever-present guard against this particular danger, its application enabling the top roll of any mill to yield sufficiently to prevent improper strains from acting upon the latter which would suffice to cause a serious breakdown.

The method of driving the two intermediate megass-carriers, which lie in their respective positions between the three mills, is seen at J and K; and these special conveyers are of light construction, travelling at lineal speeds which harmonise with the surface speeds of the rollers they serve with megass. The large second-motion spur-wheels of the compound gearing which drives the three mills are respectively located at L, M, and N, and upon turning to Fig. 60 the same three wheels are more clearly seen occupying a very prominent position in this special view of the above gearing. The engine which actuates this gearing is situated

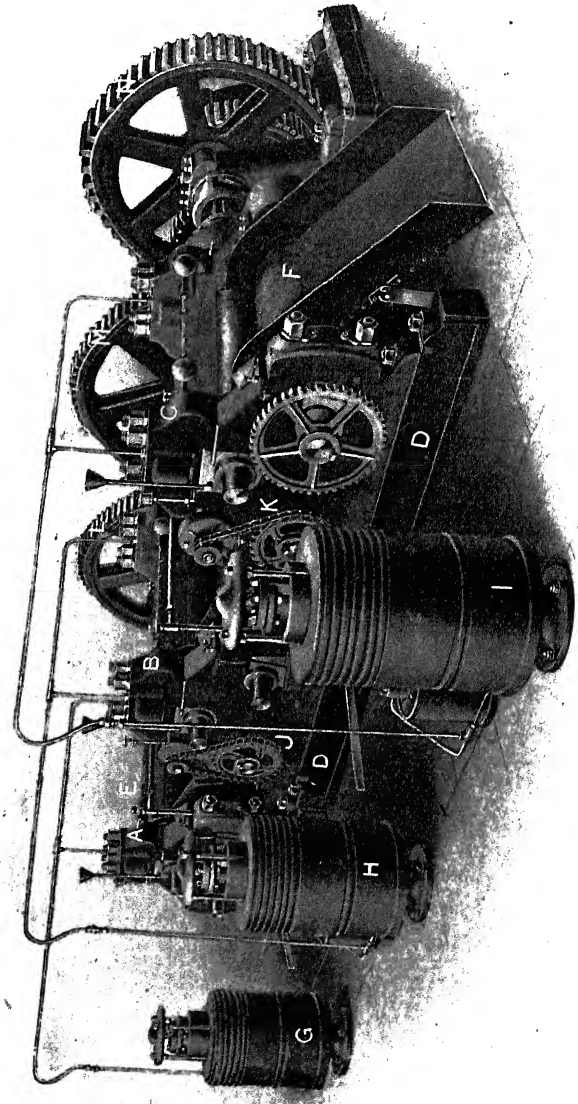


FIG. 59.—A nine-roller cane-crushing installation.

at O in Fig. 61, and the fly-wheel of this prime mover is seen at P. The engine crank-shaft, Q, extends towards the gearing, and upon its inner end is fixed the crank-shaft or first-motion pinion, which gears with both of the first-motion wheels, R and S, fixed upon the two first-motion shafts, T and U, seen in Fig. 60. Upon these shafts two second-motion pinions, W and V, are also placed in their respective positions, the latter of which gears with and works the large second-motion wheel, L, whilst the former performs the double duty of driving both the remaining second-motion wheels, M and N. The squared ends of the three powerful second-motion shafts, upon which L, M, and N are fixed, appear at X, Y, and Z, upon which are placed the massive and loosely-fitting couplings seen at X^1, Y^1, and Z^1, in Fig. 61. The three tail-bars connecting the gearing with the three mills are at A^1, A^2, and A^3 in the same illustration, and the mill-couplings which join the tail-bars to the top roller gudgeons of the three mills are at B^1, B^2, and B^3. By these means the three mills and their compound gearing are worked by one powerful engine, which thus controls the relative movements of the respective mill rolls, the surface speeds of which can be adjusted and uniformly maintained at any given ratio which may have been decided upon and arranged. The three illustrations just referred to are useful as showing the component elements of a "nine-roller" or "triple-crushing" plant, and demonstrating the respective functions and relative positions of the mills, gearing, and engine, in a manner which should enable the reader to comprehend clearly the arrangement of such an installation, both in detail and as a whole.

In the daily manipulation of a triple-crushing plant it is very rarely that imbibition is not used, and a common practice is to withdraw the diluted cane juice extracted by

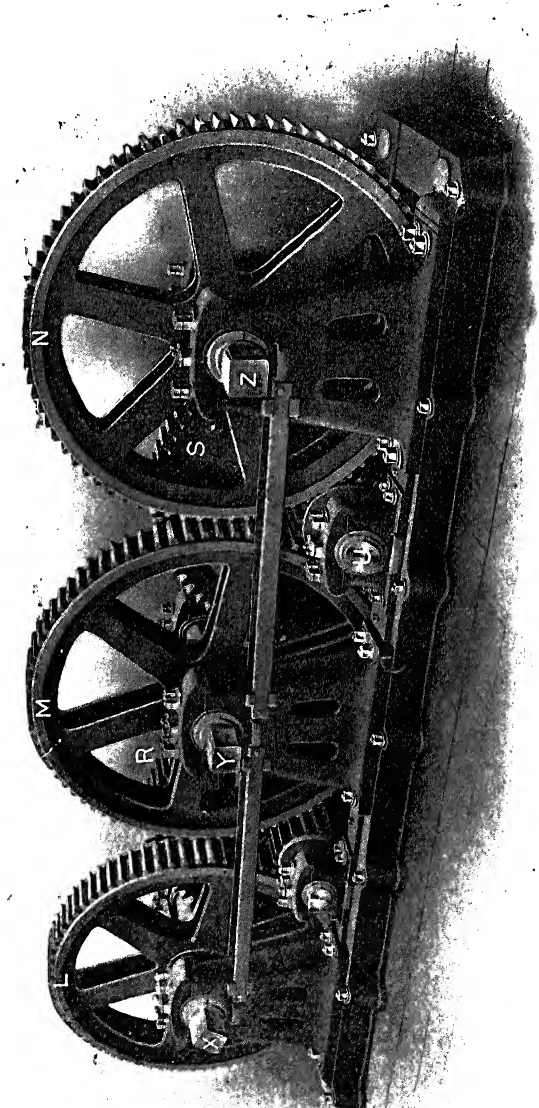


Fig. 60.—Separate view of the gearing of the installation shown in Fig. 59.

the third mill and to convey it by suitable means to the first mill, where it is applied to the megass issuing from the rolls. If desirable, this third juice may be further diluted by the addition of steam or water, and the single-crushed megass is thus soaked and prepared for more effective treatment in the second mill. In the same way, the double-crushed megass issuing from the rolls of the latter is well saturated with boiling water to prepare it for final treatment in the third mill. It is undesirable to enter as yet into any extended account of the different methods which may be adopted for effecting imbibition. Suffice it to say that it can be carried out in a variety of ways, comprising some dozen variations. The above brief example of one of the several changes that may be rung on the respective applications of second and third mill juice and steam and water, will serve to explain, for the time being, the nature and objects of such applications. At the same time, it is important to point out that the latter may be divided into two distinct classes, viz., "short bath" and "long bath" immersions. In the triple plants just considered, where the three mills are driven by the same engine, short-bath arrangements prevail; but where long-bath immersions are desired, each of the three mills has its own engine and gearing, and they are placed at considerable intervals apart from each other, as shown in Fig. 62.

There are numerous details worthy of close attention, the majority of which may be left to speak for themselves; but it is perhaps as well to mention that in multiple installations the megass is so completely disintegrated and pulverised, that it has a strong tendency to adhere in undue quantities to the surfaces of the rolls. Therefore, it will be noticed from the various illustrations that scraper-plates are used to clear the top rolls of the posterior mills of

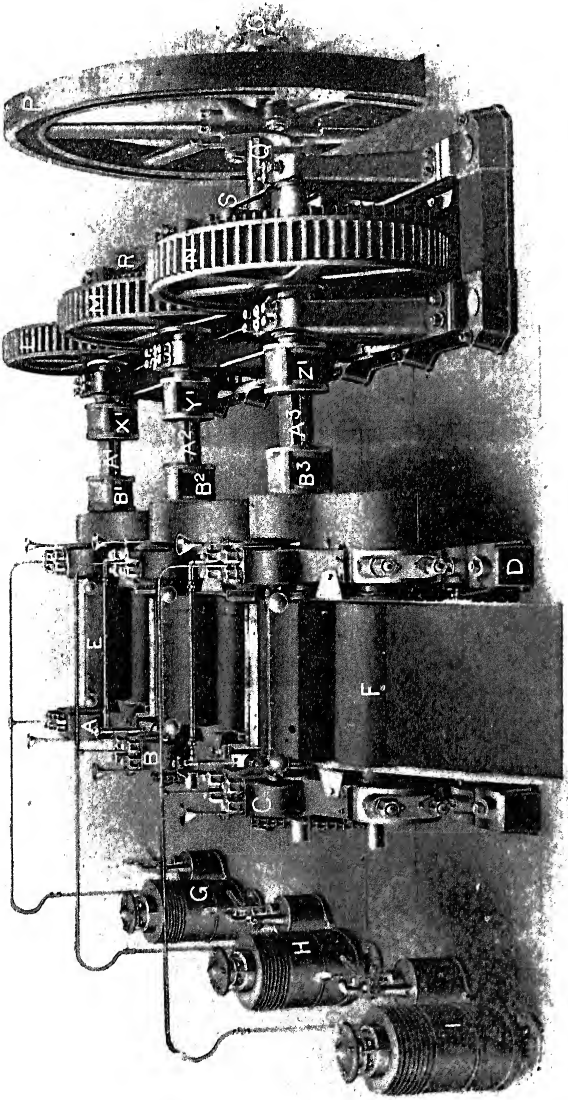


FIG. 61.—End elevation of installation shown in Fig. 59.

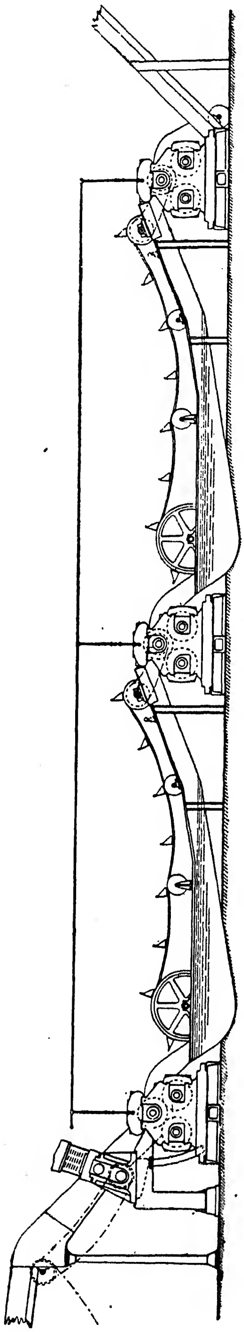


FIG. 62.—Side elevation of an eleven-roller plant as worked in connection with long-bath immersions of the megass.

adhesive substances which would otherwise interfere with the efficiency of the plant.

The otherwise convenient arrangement of placing the mills close together is, nevertheless, associated with the serious drawback that obtains in cases in which the more elaborate accessories employed, for ensuring a complete disintegration of the canes, are not in evidence. When modern shredders, assisted by other modern accessories, are employed, the mills may in all probability be kept as closely together as shown in Figs. 50 and 61, with the attainment of highly satisfactory results. But in ordinary cases, in which the customary grade of megass has to be reckoned with, it is desirable to place the successive mills at least 36 feet apart from each other. It is no use adding water to the megass, for the purposes of maceration, unless sufficient time is given to this agent to effect its share of the work of cleansing and exhausting the cane-cells, and careful investigation by competent authorities tends to the recommendation of a distance of some 40 feet between consecutive mills.

Fig. 63 is an example of an eleven-roller installation. It is similar, in its main features, to the nine-roller plant described above, but the three mills are preceded by a pair of preparatory rolls which have longitudinally grooved surfaces, and the duties which they have to perform are somewhat of the same character as those which would be executed by a Krajewski crusher. Taken from an elevated

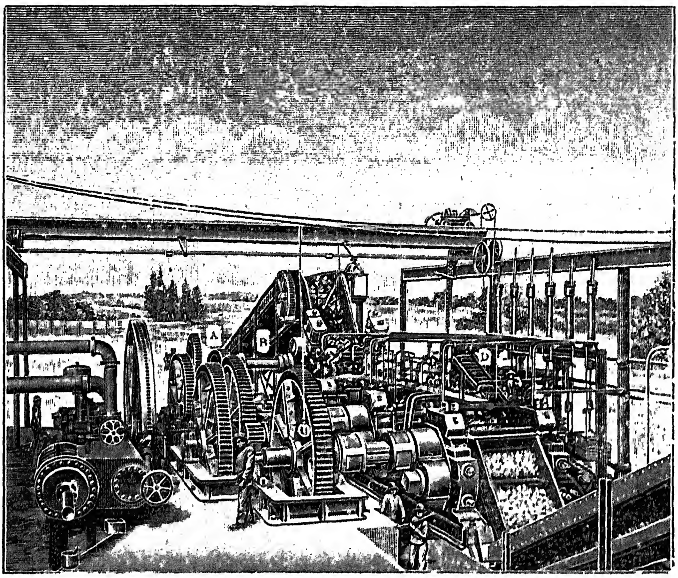


FIG. 63.—Eleven-roller cane-crushing installation, driven by one engine and double compound gearing, and consisting of three mills and two special preparatory rolls.

position, the illustration displays many details which would otherwise be hidden from view. The general arrangement of the mills is substantially the same as in the case of the nine-roller plant already referred to. There is, however, a noteworthy addition to the gearing at A, inasmuch as not merely the three mills but also two additional rollers, as just mentioned, have to be worked by the one engine; and

the fourth tail-bar, B, shows how the power is transmitted to this additional pair of preliminary rolls. An interesting view is also obtained at D of the special form of combined strainer and elevator, described in detail in a previous article, as shown in Fig. 42. The juice-pumping arrangements are seen at E, and the numerous and massive wheels of the gearing stand in a conspicuous position in the foreground of the illustration.

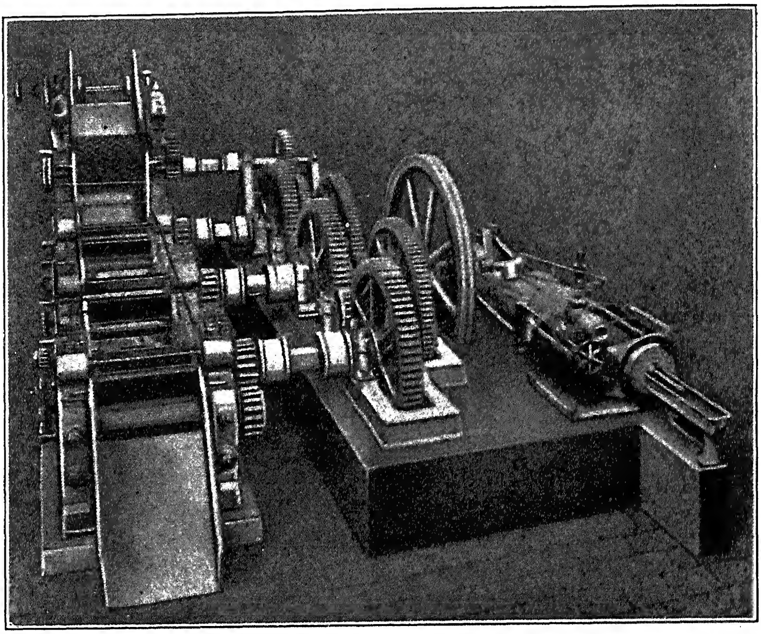


FIG. 64.—Another eleven-roller installation driven by one engine, and consisting of three mills and preparatory Krajewski crusher.

Fig. 64 gives another view of an almost identical installation, in which the details of the construction, arrangement, and method of driving the entire plant are most clearly shown right through from the engine to the mills. In this group of machinery, however, a Krajewski crusher is employed in place of the straight-grooved preliminary

rolls in Fig. 63, and it will be seen that the branch gearing for driving both the crusher and rolls is identical in principle in both arrangements. These two last illustrations are very suitable complements of each other, the one being taken from the engine side, and the other from the mill side of the respective installations; and the fullest opportunity is thus afforded of grasping the relative functions of almost every detail throughout the respective plants.

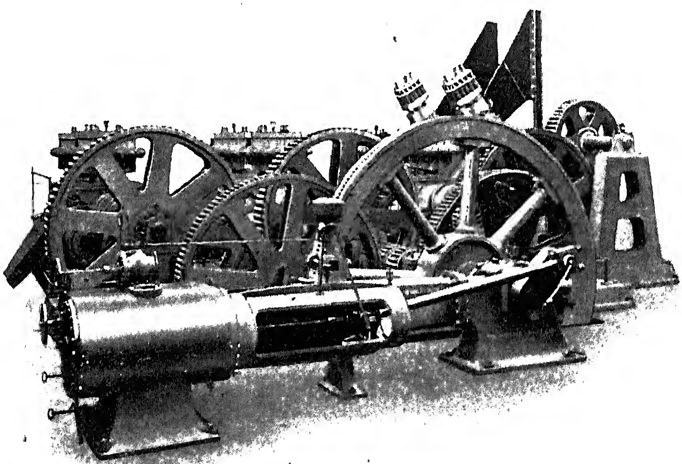


FIG. 65.—Engine and driving-gear employed to work an eleven-roller cane-crushing installation.

In most of the foregoing illustrations the powerful engine requisite to drive so many mills and such massive gearing has been somewhat crowded out of the pictures, but Fig. 65 makes good this deficiency and gives a full view of a large and suitable engine. Moreover, the details of the massive gearing are worthy of the closest attention, and it should be noticed that a special feature characterises its arrangement, inasmuch as the crank-shaft carries two pinions in place of one. Each of these pinions thus works its

own first-motion wheel instead of the more usual and solitary pinion working both wheels, and this modification offers various advantages and conveniences which render it worthy of notice. The three mills worked by this gearing are preceded by a Krajewski crusher, and the extension of the gear for driving the latter is clearly seen to the right hand of this group of machinery. It will also be noticed that toggle gear is fitted to each of the mills.

Fig. 66 similarly gives equal facilities for studying the constructive details of the gearing which has to be employed to drive an installation of eleven rollers, of the same class as that portrayed in the preceding illustration. In most of the earlier pictures this combination of gear wheels has been considerably foreshortened. Here it is shown at full length; and the method of building up the large motion wheels is well seen. The massive squared ends of the four motion-shafts, which couple with the roller gudgeons of the crusher and the three mills, through the intermediate agency of the four tail-bars (as seen in earlier illustrations), are very noticeable; and the method of attaching the various large plummer-blocks to the standard brackets and massive main gearing bed is clearly defined.

It is now necessary to consider the question of the increased extraction of the juice from the canes, which is effected by the employment of such extensive and powerful installations. Proceeding on the same basis as that adopted in the estimates of the work done by single and double mills, it is found that with the use of nine and eleven-roller installations in the form of triple mills with a preliminary crusher, as shown in the various illustrations, and the application to the megass of suitable quantities of added water, a total extraction is obtained of, say, 92 per cent. of the total sugar originally contained in the canes, the re-

mainder, 8 per cent., being lost in the megass and burnt in the boiler furnaces.

At this stage it will be of interest to quote again the previous figures, plus the last two quantities, which should prove of assistance in definitely pointing out the relative position of the higher degree of extraction which has now been reached through the employment of triple installations:—

	Percentage of Sugar obtained on Total Sugar in Canes.	*Percentage of Sugar lost in the Megass on Total Sugar in Canes.*
Single milling	76·00	24·00
Double milling (dry) . .	83·00	17·00
" " (wet) . .	86·00	14·00
Treble milling (with crusher)	92·00	8·00
Diffusion	96·00	4·00

In considering these figures, it has to be borne in mind that the degree of extraction obtainable largely depends upon the comparative quantities of added water applied to the megass, which in the above figures relative to the work of treble mills amounts to a dilution of some 25 per cent. of the normal juice obtained through the agency of the first mill of the series, or in other words an approximate dilution of 20 per cent. of the total normal juice obtained through the agency of the three mills of the complete plant. In the case of careful work performed by diffusion, the tabulated sugar extraction effected by its aid would be obtained through the action of a dilution of some 25 per cent. of the total normal juice extracted from the sliced canes; leaving a margin in favour of a more complete extraction which might be effected even by triple-crushing provided a more copious dilution of the normal mill juice were attempted, coupled with the use of a pair of preliminary rolls similar to those shown in Figs. 63 and 64.

In striving for the attainment, through the use of mills,

of a more or less complete extraction of sugar from the canes, the question of the dilution of the normal cane juice has to be closely watched, and it occupies different conditional positions in the respective processes of milling and diffusion. In the former process its extensive application is, comparatively speaking, more or less optional; in the latter it is imperative. In the former it is an additional means of obtaining an additional extraction; in the latter it is an inseparable expression and the foundation and chief instrument of all extraction, whether partial or complete.

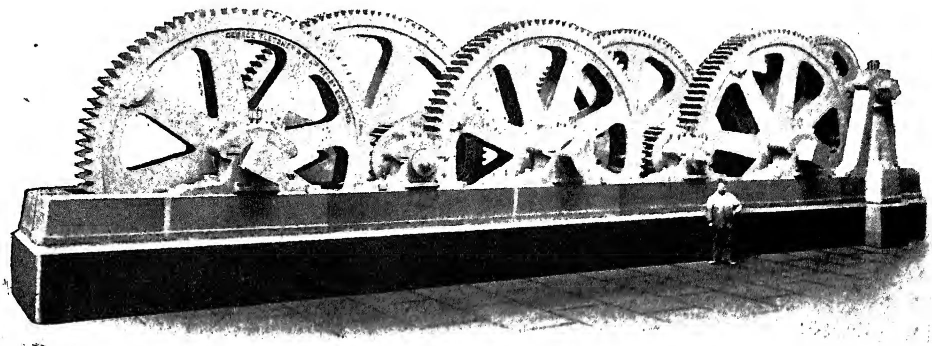


FIG. 66.—Full side elevation of compound motion gearing employed to communicate the engine-power to an eleven-roller installation similar to that shown in illustration No. 63.

If in connection with either mills or diffusion, twenty-five tons of water are added to one hundred tons of normal cane juice, a dilution of 25 per cent. is effected, which is always concisely referred to and expressed as "25 per cent. dilution." In the case of diffusion, it is the persuasive and natural agent which completely supplants the crushing force of cane-mills. In the case of mills, it is the supplementary and cleansing agent which more or less refills the partially emptied cane-cells, and ultimately, under the compulsory action of further subsequent pressure, washes out

the remainder of the sugar from the cells which still clings to their walls in opposition to the efforts of previous pressure. In return for this efficacious service it saddles both methods of extraction with certain drawbacks, and should therefore always be introduced as sparingly as possible. Although nominally only 25 per cent. water may have been added to the normal juice, it nevertheless means that some 30 per cent. more water has ultimately to be voided by evaporation than would be the case with equal quantities of normal undiluted mill juice, thus increasing the expenses of subsequent manufacture into sugar.

In the operation of cleansing any vessel or cell from contained substances, it is well understood that repeated and more frequent successive applications of smaller quantities of the selected washing medium are more efficacious than a single application of the same total quantity in one collective portion. This is an axiomatic fact which is easily supported by theoretical calculations referring to this phase of imbibition. It also largely accounts for the growing preference which is shown nowadays for multiple mills of an increased multiplicity. Thus, in dealing with any given quantity of canes, the tendency of present practice, other things being equal, is to employ a succession of smaller and more numerous mills, rather than a fewer number of larger unit size. Generally speaking, single-crushed megass is not always sufficiently disintegrated to render it capable of satisfactorily absorbing the applied diluent. The more finely the canes are crushed, the more efficiently the megass will absorb the added fluids, and the increased number of mills employed offer more frequent and more satisfactory opportunities for imbibition. Coupling these considerations with a full appreciation of the additional facilities provided for a greater range by any convenient distribution of the total work to

be done over the entire extent of the available machinery, it is not altogether surprising to find that eleven, twelve, fourteen, and even seventeen-roller installations are now being used.

At the same time it is important to realise the fact that the use of these extended installations should not lead to, or encourage, carelessness in maintaining, according to circumstances, the fullest efficiency of the first or earlier mills, for inefficient dry-crushing is prejudicial to the attainment of the best results which would otherwise be obtained through the aid of maceration in conjunction with the use of the succeeding mills of the complete train. As a matter of general practice, it is usually desirable to obtain a maximum dry expression, coupled with the return of the diluted juices from the later to the megass from the earlier mills.

Fig. 68 shows one way in which four three-roller mills and the preliminary crusher and shredder of a fourteen-roller plant are arranged with reference to each other. Similarly Fig. 69 explains how the mill engines and their respective sets of gearing are disposed, whilst Fig. 67 gives an end elevation of the complete plant. Turning to Fig. 70, a plan of the entire arrangement of the machinery is clearly displayed, and a full opportunity afforded of appreciating the various details of the general disposal of this extensive and powerful installation.

A general view of another installation of four mills is shown in Fig. 71. This plant is fitted with rollers 34 in. in diameter by 78 in. in length, preceded by a Krajewski crusher having two rollers 26 in. diameter by 78 in. long, and one of the first points which will attract attention has reference to the circumstance that in this case it has been decided to employ two engines to drive the train of mills. Each of these engines has a steam cylinder

diameter by 51 in. but whilst the first is to run at the rate evolutions per minute, ond will make 51 revo- per minute. Although four mills with their nary crusher are in- to be used as an machine, and must considered in relation r work as extractors, 'e nevertheless struc- a combination of two apparatus. The first drives a tandem six- plant, preceded by a , as already described ection with Figs. 53 t. This preliminary tion is then followed ther six-roller plant, a crusher, driven second engine (see 0 and 69); the con- link between the two consisting of the con- nal feature that the ills and crusher are nted upon the same ous massive gantry, ombines the four mills, eir details and acces- n the same element.

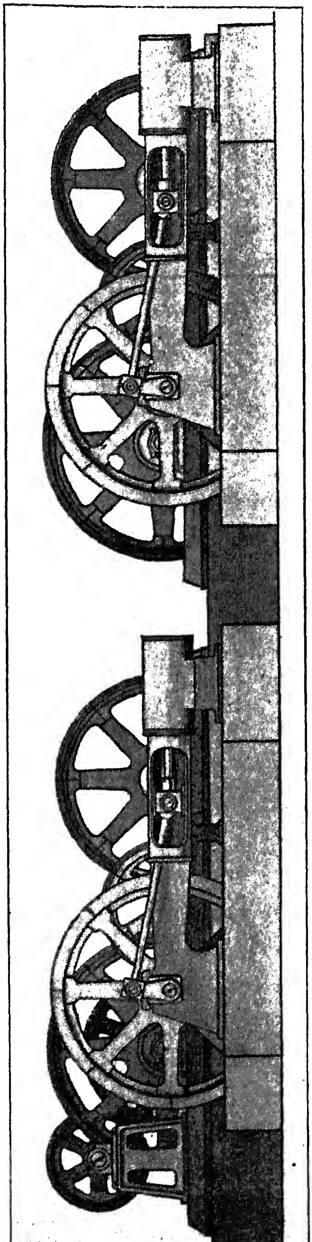


FIG. 69.—Side-elevation of two engines and sets of gearing, as arranged, for driving a fourteen-roller installation.

Some experts especially welcome such an arrangem and advocate the devotion of the full power of the engine and its accompanying eight rollers and gearin dry-crushing pure and simple. Imbibition is then be in connection with the megass emerging from the rolls o second mill, and the action of maceration is confined to work of the second section of the plant. Some advoc indeed go a step further. Having decided upon the ployment of two engines, the two sections of this insta tion (although still worked as a single fourteen-roller tractor) would be kept farther apart from each other, a long-bath immersion of diluted juice would be instit between the second and third mills, whilst hot water wo be applied to the megass issuing from the rolls of the t mill. It is extremely important to note this diverge from the more usually recognised practice, this bein point which has been emphasised by various authorit

It is now necessary more specially to consider the p shown in Fig. 71, and to deal with its details in t integrity, and the nature of its application as inten by the planters who have ordered it, briefly describing manner in which the more dilute juices and added water manipulated in the process of maceration. It consists already mentioned, of four tandem cane-mills, preceded a Krajewski crusher, worked through the agency of independent sets of double compound gearing, each of latter being driven by a separate engine of the sizes gi above. The machinery is of the strongest possible c struction throughout, the complete plant being capabl effectually crushing 1250 tons of cane per day at the r of, say, some 54 tons of cane per hour; and as this extens group of machinery embodies numerous details which h already been noticed in these pages, a fuller and m minute reference to its details will be attempted than

hitherto been made in connection with any of the earlier installations. At the same time no reference letters are given, as by this time readers will be sufficiently conversant with the details, and special references should thus be unnecessary.

Hydraulic pressure-regulating apparatus has been adopted in preference to the employment of compressed air, or toggle-gear, and in accordance with past experience it is applied to each megass roller, and each mill is provided with two hydraulic accumulators, in order that the exact requisite pressures may be ensured for the opposite journals of each megass roller gudgeon. The total pressures applied to each mill will begin at 254 tons for the first mill, 270 for the second, 285 for the third, and 301 tons for the fourth; but the hydraulic apparatus is designed so that each of these total pressures may, if found desirable, be increased up to 500 tons on each mill.

The canes are brought to the Krajewski crusher by means of an extra heavy cane-carrier entirely supported on a steel framework, this carrier being usually driven by its own independent engine. Alternative provision, however, is also made to work it from the main gearing of the mills when necessary, and it should also be mentioned that the level portion of this carrier is placed in a brick-lined pit below the ground-level. The Krajewski rollers are of cast steel, and their surfaces are corrugated in the special manner suitable to the preliminary breaking up of the canes. They are also fitted with direct-acting spring regulators, which act upon the rolls through the agency of plungers passing through the top caps of the crusher head-stocks. These plungers, in turn, bear direct on strong steel pads, which distribute the pressure over the entire upper surfaces of the top roller journal brasses. The top caps of the headstocks can therefore be firmly bolted down to fixed

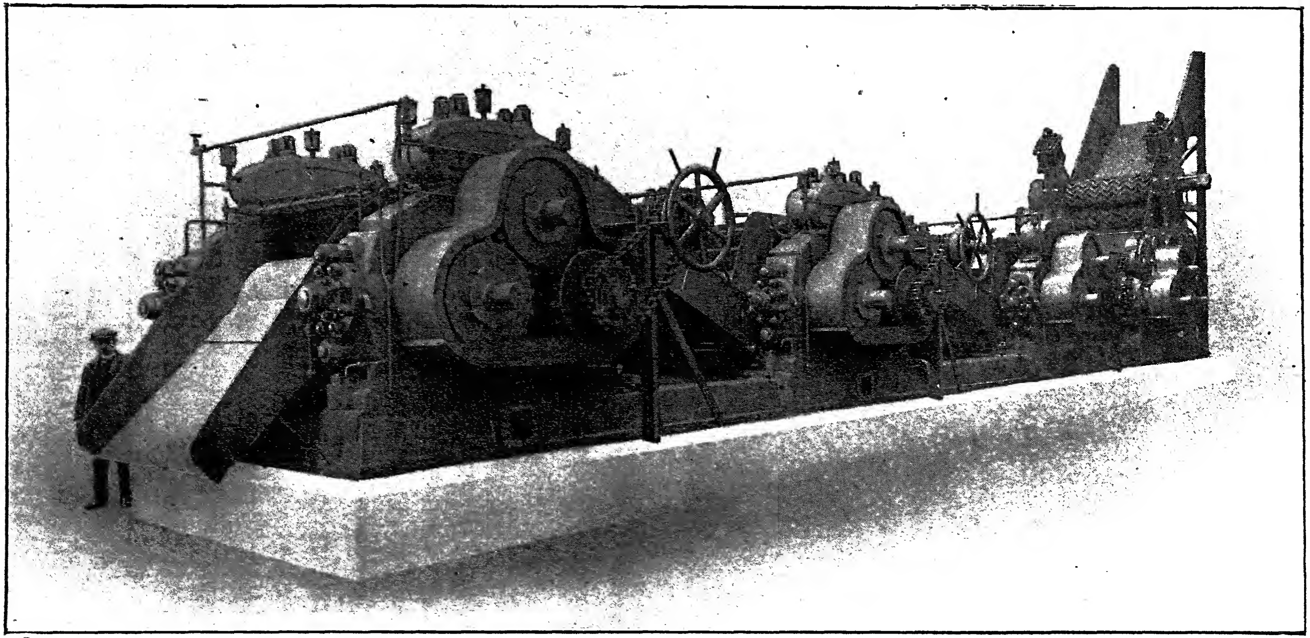


FIG. 71.—A fourteen-roller mill plant.

positions, thus forming integral portions of the crusher framework, and the use of plungers, in place of rising and falling caps, adds to the sensitiveness of the applied pressure. It will be noticed that when the crusher is driven off the main gearing, it is then actuated by a special spur wheel fixed on the second-motion shaft of the first mill. This spur wheel gears with another wheel on the crusher driving-shaft which is connected to the bottom gudgeon of the crusher by means of a tail-bar and couplings, these arrangements providing for the free vertical movement of the Krajewski top roller.

The partially squeezed canes from the crusher descend by gravity to the first mill, through which they pass, being then conveyed, in the form of megass, by means of the intermediate carrier to the second mill, subsequently passing in the same way through the third and fourth mills, until the finally crushed and highly pulverised megass is ultimately delivered on to a conveyer which takes it to the furnaces, where it is used as fuel for steam-raising purposes in connection with the entire factory. The intermediate carriers, fixed between the respective mills, are of the continuous blanket type, fitted with specially designed corrugated and overlapping steel slats, attached to malleable cast chains running over anti-friction rollers.

The disposition and special arrangements of the two sets of massive gearing, which drive any such four mills, are shown in Fig. 69; and for the sake of uniformity the gearing and engine driving the third and fourth mills are identical in strength and details of construction with those driving the first and second. The mill pinions, gearing pinions, and all the toothed segments of the various wheels throughout, are of cast steel, shrouded to near the pitch line; whilst the journal brasses of all the mills are fitted with water-jackets, through which a con-

tinuous supply of cold water is circulated by means of a system of service pipes, in order to keep the various bearings cool. In addition to these arrangements, all the mill and gearing journals are provided throughout the entire installation with large automatic sight drop lubricators for the purpose of ensuring perfect and economical lubrication.

There are two sets of automatic juice strainers and elevators, with their accompanying screw conveyers, juice tanks and pumps. They deal with the expressed juices issuing from the crusher and the four mills, and manipulate and distribute them in the manner required for the respective purposes of either imbibition or sugar-making.

Turning attention to the methods to be adopted in the use of such an installation, it should be observed that the juice from the Krajewski crusher is usually delivered by a steeply sloping trough into the bed-plate of the first mill. It thus mixes with the juice expressed by this mill, and the combined juices pass through the first portion of the first mechanical strainer. The tank immediately beneath this strainer is divided into two sections, into the first of which the foregoing mixture of juices is delivered. The juice from the second mill is strained through a succeeding portion of the same strainer, and passes thence into the second section of the afore-mentioned tank. These two streams of juice are thus kept separate from each other until they ultimately unite in a third tank, whence they are pumped together up to the clarifier loft of the sugar house, where they undergo the process of clarification. Owing to this arrangement separate samples may at any time be drawn from the juice products of the first and second mills for the purpose of the chemical supervision and control of the work of the entire milling plant.

The cush-cush from the above strainer is raised by its elevator, and delivered into a screw conveyer of the usual

type, which in turn discharges it through openings in the bottom of the conveyer trough on to the intermediate carrier between the second and third mills. These openings in the trough are adjustable, and extend over the entire width of the intermediate carrier, with a view to a uniform distribution of the cush-cush, in contradistinction to the frequent and objectionable practice of delivering all of it to one point. The juice from the third mill is strained through the first section of the second mechanical strainer, whence it is pumped by a small duplex pump to the megass delivery shoot of the first mill, for the purposes of imbibition. Here it is distributed by a special device on to the megass issuing from this mill, thus effecting the first stage of maceration or imbibition. The juice from the fourth mill is strained through the second portion of the second strainer, and being very dilute, and consisting of little more than added maceration water, is pumped by another separate duplex pump to the delivery shoot of the second mill. Here it is applied to the megass issuing from that mill, and in a manner similar to that described in relation to the first mill, thus effecting the second stage of maceration. The cush-cush from the second strainer, as with the first, is similarly raised by a second elevator, and uniformly delivered on to the carrier located between the third and fourth mills. With regard to the particular disposal of the cush-cush, here described, it is desirable again to call special attention to the remarks made on this subject at the close of Chapter III. (Accessories and their Functions). As the megass issues from the rolls of the third mill, it is treated with water alone, thus effecting the third stage of maceration; and it is at this particular point that the bulk of the added extraneous water of imbibition is applied; and it is this application which accounts for the highly diluted juice that runs from the last or fourth mill,

to which reference has already been made. Nevertheless, provision is also made in connection with the first and second maceration carriers whereby additional quantities of water can be applied at earlier stages of the crushing when desirable. Thus water may, as required, be injected under pressure into the megass the instant it emerges from

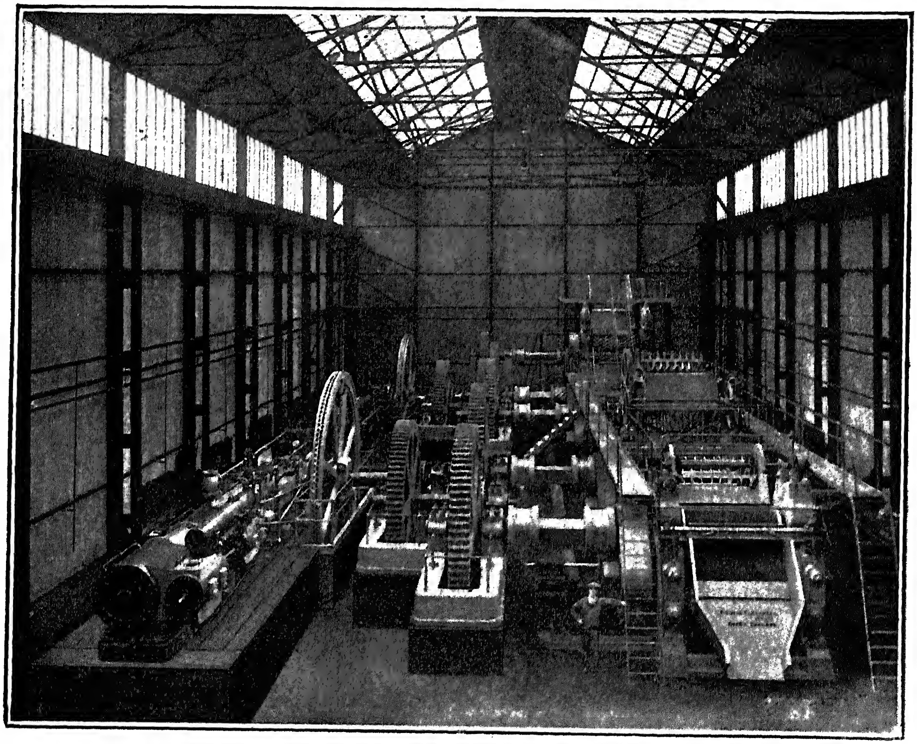


FIG. 71A.—Fourteen-roller installation.

the rolls of each of the first three mills, or while it is in the act of passing from the delivery shoot on to the paddles of the intermediate carriers.

It will thus be seen that by the employment of the principle of a gradual dilution of the juice contained in the megass as it progresses from mill to mill, coupled with the

return of the more dilute juices to points situated between the first and second, and third and fourth mills, the maximum extraction is promoted in conjunction with minimum dilution. The yield of sugar obtained from the canes through the agency of such an installation as this is comparable with similar results obtained by diffusion, as will be seen by the final table given below, which embodies previous figures already set out, coupled with an indication of results which may be obtained through the use of the more extended installations:—

	Percentage of Sugar obtained in Juice on Total Sugar in Canes.	*Percentage of Sugar lost in Juice on Total Sugar in Canes.*
Single crushing	76·00	24·00
,, ,, with preliminary crusher	80·00	20·00
Double crushing (dry)	83·00	17·00
,, ,, ,, with crusher	85·00	15·00
Double crushing (with 10 per cent. dilution, without crusher) ..	86·00	14·00
Double crushing (with 10 per cent. dilution, with crusher)	88·00	12·00
Treble crushing (with crusher and 20 per cent. dilution)	92·00	8·00
Quadruple crushing (with crusher and 20 per cent. dilution) ..	94·00	6·00
Quadruple crushing (with crusher, shredder and 25% dilution) ..	96·00	4·00
Diffusion, with 25 per cent. dilution	96·00	4·00

Fig. 71A gives a very interesting view of another fourteen-roller installation of recent design and construction.

CHAPTER V

CLARIFICATION OF THE JUICE

THE clarification of the juice sent from the mill to the boiling-house must now be dealt with, and it should here be mentioned that, as a general rule, estates' engineers have not in the past paid sufficient personal attention to this most important question of thoroughly efficient clarification, which, in the progress of time and experience, is continually the subject of increasing attention and investigation. This comparative neglect on the part of the engineering faculty is largely due to the feeling that clarification is in the hands of the chemist, as undoubtedly it is to a major extent. But it is the foundation-stone of all satisfactory work, not only with regard to a maximum recovery of good sugar, but likewise with reference to the satisfactory employment of all the heating, evaporating, crystallising, and sugar-curing appliances throughout the factory. Many heaters and multiple-effects fail in the performance of their maximum duty through the drawbacks due to inefficient clarification, and multiple-effects are especial victims to these shortcomings.

With perfect clarification, the multiple-effect should merely require cleaning once a week, and such weekly cleaning should prove to be a comparatively light operation; whereas, with imperfect clarification, the operation of cleaning the effect frequently becomes involved in almost insuperable difficulties; and throughout the week's work, avoidable delays, loss of fuel, together with other serious

inconveniences are experienced, right up to the sugar-store, which, by proper attention to this all-important section of sugar manufacture, should be altogether avoided. As a matter of self-protection, and as a question of ensuring the efficient working of certain apparatus, for which he is primarily responsible, as well as for the effective and economical employment of the exhaust-steam from the factory engines, together with the proper working of the centrifugals, it is necessary for the engineer to pay the closest attention to the clarification plant, and to maintain all its details in a condition of the fullest efficiency. The first point requiring attention is to see that there is an undoubted sufficiency of defecator or clarifier accommodation; and, to meet all probable and possible requirements, these vessels should possess a gross capacity of at least 500 gallons juice for each ton of canes ground per hour. Thus, for dealing with the cane juice coming from, say, 20 tons canes ground per hour, in other words good and thorough extraction effected by a train of three mills and crusher, having rolls 30 in. diameter by 60 in. in length, the gross accommodation of the clarifiers should amount to at least 10,000 to 12,000 gallons cane juice.

The next point is to see that the heating surfaces of these vessels are in good order and provided with proper steam-supply and condensed-steam withdrawal arrangements, and that the hot water coming from the latter is carefully returned to the boiler-house. Thirdly, as a matter of fuel economy alone, close attention should be paid to the best methods of heating the cane juice on its way from the mills to the clarifiers, the administration of such heat being preferably performed by the otherwise wasted vapour from the multiple-effect and vacuum-pans on its way to the central condenser; by double-effect in a heater attached to the first vessel of the multiple-effect; and finally by the

employment of a well-designed exhaust-steam heater placed close to the clarifiers. (See remarks on multiple effects in Chapter VII.) By means of these preliminary arrangements the cane juice can be economically brought to the clarifiers at a temperature of some 200° Fahr., so that a very brief application of high-pressure steam direct from the boilers meets the final requirements of effective clarification. It is even desirable to consider also the employment of heaters to each and all of the vessels of the multiple-effect.

The juice running from the mill is turbid, yellowish or greyish green in colour, with fine fragments of cush-cush, or particles of the fibre or rind of the cane, together with some of the clay or sand adhering to the cane, mixed with it. It has now to be treated so that the impurities may be got rid of as far as possible before it is submitted to concentration. The bulk of the cush-cush is primarily removed by one or other of the various types of the fine wire-mesh strainers, which have been fully described and illustrated in a previous chapter, and further and more drastic treatment of a similar character may be applied through the subsequent agency of various arrangements of still finer wire strainers, which may be introduced in the clarifier loft, either at the ends of the gutter which has conveyed the juice from the mill-house, or which may take the form of mechanical and automatic appliances that are self-acting and dispense with excessive manual assistance. The soluble impurities consist mainly of albuminous and colouring matters, gums and mineral matter. There is also present a varying quantity of uncrystallisable sugar, commonly known as glucose, but differing from glucose in that it is doubtful if it has any action on polarised light. It would be unfair to rank this body as an impurity, although it is not crystallisable in the sense that cane sugar is, as it forms an item of considerable

value in molasses. In canes which are not freshly cut, or which have been injured, there is a certain amount of invert sugar, consisting of equal parts of lævulose or left-hand, and dextrose or right hand, polarising sugar. At one time these bodies were supposed to exercise special action in preventing and retarding the crystallisation of cane sugar, but this view has now been abandoned.

There is great variation in the proportions in which the constituents of cane juice exist in it; but the following may be taken as being representative of an average sample:—

	Per Cent.
Water	83·00
Cane sugar	15·00
Uncrystallisable sugar	1·00
Albuminous and colouring matter, Gums	0·50
Mineral matter	0·50

Not only does the composition of the juice of different varieties of cane present considerable variation under similar conditions, but the degree of ripeness has an important bearing on its composition. In unripe canes the impurities and uncrystallisable sugar are in higher proportion to the cane sugar than in ripe canes, the proportion diminishing as the canes approach maturity.

An additional and important factor in this respect is the degree of crushing and maceration to which the canes have been subjected. With the primitive cattle and windmills which at one time constituted the most efficient methods of extraction, and are still extant in a few cane-growing countries, the crushing is practically confined to the soft cellular portions of the cane, and a correspondingly pure juice is obtained. With steam plants, however, a greater grinding action occurs, which results in the fibro-vascular bundles, containing the impure sap-juice, being more or

less broken up, and their contents mixed with the purer juice from the cell structure. The result is that juice from the same canes contains more or less impurities according to the degree of extraction, the maximum of impurity, *ceteris paribus*, being reached with triple and quadruple mills, with preliminary crusher and maceration. The following is an illustrative example of the effect of multiple grinding on the purity of cane juice, where no maceration has been employed:—

	Juice.			Solids.		
	Sucrose. Per Cent.	*Glucose. Per Cent.*		*Sucrose. Per Cent.*	*Glucose. Per Cent.*	*Impurity. Per Cent.*
Crusher ..	16·86	2·36	..	84·94	11·89	3·17
First mill ..	16·40	2·09	..	83·89	10·70	5·41
Second mill ..	16·01	2·09	..	82·38	10·77	6·81
Third mill ..	15·81	1·91	..	82·15	9·91	7·94

Fresh cane juice has a faintly acid reaction, which is much greater in juice from unripe or damaged canes. If the acidity be increased, either by the addition of acids or by spontaneous acidification, a certain amount of separation of impurities takes place. All methods of clarification, however, when conducted on a scale of any magnitude, are based on the use of an alkali—almost invariably lime, in association with heat. Cane juice, as expressed from the mill, contains microscopic granular bodies which develop a ferment when exposed to the air. The effect of this ferment is to produce rapid acidification of the juice, and it is therefore of primary importance that cane juice be treated as soon as possible after it comes from the mill. Juice which has been passed through filter paper, and thus separated from these organisms, can be kept for some time without change, but when juice is allowed to stand in its normal state a rapid change takes place.

In primeval methods of sugar-making, potash was, as a

matter of fact, the main clarifying agent used. The juice, extracted by crude presses, was transferred to a pot heated by means of a wood fire. As the temperature of the juice rose, the ashes of the fire, which would contain carbonate of potash, were added in the required proportions to it, the impurities being skimmed off as they came to the surface, until the juice was sufficiently clean for concentration to graining point, an operation which was carried out in one and the same vessel. Later on when the sugar-cane began to be cultivated on a larger scale, and wind or water-mills were used to extract the juice, concentration by means of the "copper wall" (see Chapter VII.) came into use. In the first two or three vessels of these clarification was effected. Wood ashes were still used, but quicklime was mixed with it; the carbonate of potash being thus reduced to the state of caustic potash. In addition, the juices of various herbs were employed, and the process of clarification became one of considerable intricacy, requiring a large amount of experience and skill on the part of the sugar-boiler. Potash is, however, an extremely unsatisfactory agent for clarification, as it produces salts which interfere considerably with crystallisation. Its use ultimately gave way to that of lime, although in India at the present day the great bulk of the raw sugar is made by small cultivators who use carbonate of soda and sometimes the roots of plants in clarification. Fig. 72 which is taken from the work of Père Labat,[1] published early in the eighteenth century, shows a plan of a sugar factory in Guadeloupe, in which the copper wall is shown. In this instance the finishing touch to the clarification, in the form of a decoction of herbs, was given in the copper styled *la lessive*.

The main object of clarification is to get rid as far as

[1] "Nouveau Voyage aux Iles de l'Amérique." Par le Père Jean-Baptiste Labat. MDCCXXII. Paris.

possible of the albuminous and colouring matters in the cane juice, together with any gums which may be present. The latter, however, as already mentioned, are not found to any serious extent in sound juice, although with the high mill extraction which is now practised, the quantity of gums

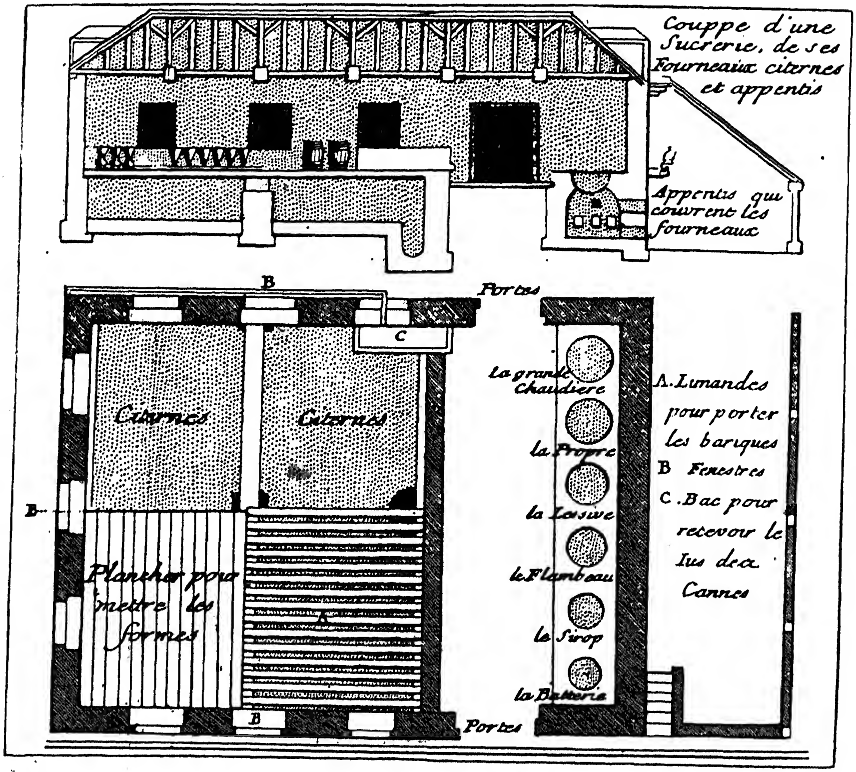


FIG. 72.—Plan of a seventeenth-century sugar factory, showing the "coppers" in which clarification was effected.

present with even sound canes tends to increase. With immature or diseased canes the juice may contain a considerable proportion of these objectionable bodies, the removal of which, in presence of uncrystallisable sugar, is attended with considerable difficulty. A large amount of

lime is required to effect their precipitation, and the result of the action of this excess on the uncrystallisable sugar is not only to discolour the juice, but also to produce bodies which have a prejudicial effect on the crystallisation of the cane sugar itself.

At the present day, the systems of clarification in use in cane-sugar factories may be divided into four classes:—

(1) For muscovado sugar.
(2) For refining crystals.
(3) For Demerara yellow crystals.
(4) For white sugar.

Dealing with these *seriatim*, it may be said with regard to (1), that muscovado works are still extant where clarification is carried out on the "copper wall." In the first vessel, or "grand copper," the lime, in the form of milk of lime of a fixed density, is added, the addition being made from time to time as the juice requires it. As the impurities come to the surface, they are removed by flat or slightly concave perforated skimmers. The juice from the "grand copper" is transferred to the second copper, where it is brought to the boil, further removal of impurities being effected by "brushing" the flocculent portions on the surface of the foam which rises into a gutter with long oar-shaped paddles. The process is practically a continuous one. This method, however, is confined to quite small works, and the usual method where muscovado is made on any scale is to employ clarifiers, as with the manufacture of refining crystals, "skimming" and "brushing" still being carried out, however, though to a less extent, on the copper wall.

(2) The form of clarifier which was at one time mostly in use in cane-sugar factories where evaporation is carried out mainly or entirely *in vacuo* was what is commonly

known as the "French" defecator. This defecator and its construction will be understood by a reference to Fig. 73. A is a spherically shaped cast-iron casing of considerable strength, fitted with an inner copper jacket, B. The intervening space, C, is supplied with live steam through the stop-valve, D, the condensed steam flowing away through the small orifice, E, which is controlled by a steam trap. The upper and cylindrical portion, F, of the defecator consists of a copper or iron curb to give the required capacity. G is a plug pipe, which is frequently supplied in the form of a simple iron rod or stem with handle at its upper end, enabling the plug to be readily removed for the purpose of washing out the defecator. H is a brass two-way cock which directs the treated contents of the defecator, as required, either through one of its branches into the clear juice gutter, or through the other into the turbid juice or washings gutter. The juice as it comes from the mill is, after straining, pumped into the defecator. When the latter is almost full, space being left for the scum to rise without the defecator overflowing, lime is added until the acidity of the juice is almost, if not exactly, neutralised, or even in some cases made slightly alkaline. The determination of this point must be based on the result of experience, as no fixed rule can be laid down as to the amount of lime which should be used, or to the reaction to be obtained. The clarified juice should be of a clear olive-green colour, and this will be generally found to go with a slightly acid or neutral reaction to litmus paper. Steam is now turned on, and the temperature gradually raised. A thick scum or blanket rises, formed of impurities which rise to the surface, aided by small bubbles of air driven out of solution in the juice by the rising temperature. The operation is complete when signs of incipient boiling occur; but on no account must the juice be actually allowed to boil. After

standing for a short time to permit of any impurities subsiding which are of too great a density to rise to the surface, the clear liquor is drawn off through H (see Fig. 73), the scum and subsidings being subsequently run off to the scum tanks for further treatment. This process affords an excellent clarification, but has been given up almost entirely for refining sugar, partly on account of the great cost of construction and maintenance of the apparatus, and partly

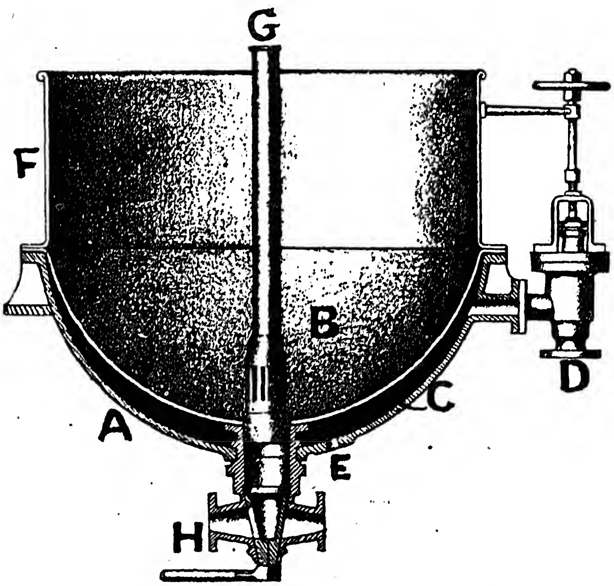


FIG. 73.—Section of a French defecator.

from high-pressure steam having to be used. Preliminary heating to, say, 130° to 200° Fahr. is usually effected by juice-heaters (see Figs. 76 and 77), in conjunction with this class of clarification, so as to minimise the use of high-pressure steam; and in connection with this point, special attention may be directed to the introductory remarks at the commencement of this chapter, and to similar indications noted in connection with multiple-effect accessories in

Chapter VII. Where white sugars are made the French defecator is still used to some extent, the great point about this system of clarification, as compared with others, being that the juice is not brought to the atmospheric boiling temperature.

Instead of the French defecator, the rectangular clarifier shown in Fig. 74 was largely used at one time. This, though cheaper in construction, is not nearly so efficient as the French defecator, and has practically passed out of use. The constructional details of this particular form of clarifier will be readily understood through an

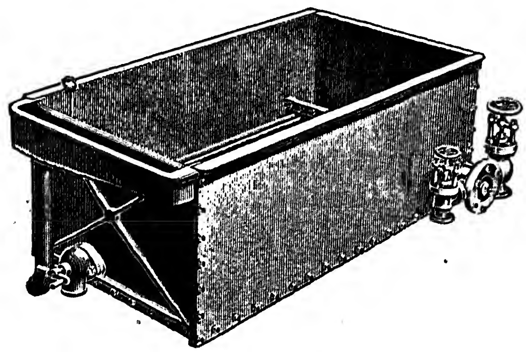


FIG. 74.—General view of an ordinary rectangular clarifier.

examination of Fig. 75, which shows the disposition of the heating surface, lying in its working position at A, which is so arranged and held in position at B in specially designed trunnion stuffing boxes, that the heating tubes can be readily lifted into the position C to allow of an easy washing out of the clarifier at stated intervals.

The system which is now mainly adopted in the manufacture of refining sugar is one in which the juice, as it leaves the mill, passes through a juice-heater. This consists of a strong cast-iron vessel, A (Figs. 76 and 77), carried on suitable supporting feet, B. Two brass or steel tube-

plates are fixed at C and D, into which are expanded a large number of solid drawn brass tubes, as shown at E. Steam is admitted into the body of the heater through the branch inlet, F, and surrounds the external surface of the tubes, the condensed steam draining itself away through the outlet G, which as usual is controlled by a steam trap. Cast-iron upper and lower juice chambers, H and I, are firmly attached to the body of the heater, and the cane juice is

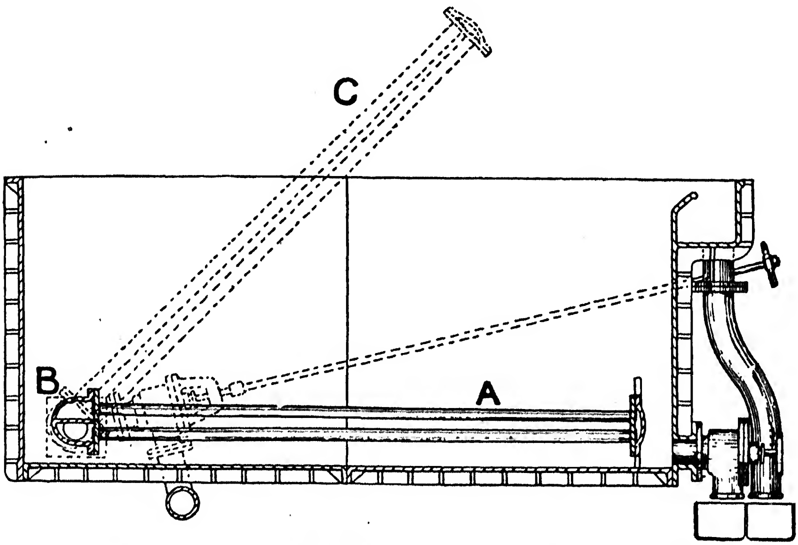


FIG. 75.—Section of a rectangular clarifier, showing the disposition of the heating surface and the various fittings and accessories.

pumped into the lower chamber through the inlet branch, J, and, rising through the tubes into the upper chamber, is heated in its passage, ultimately passing out of the heater through the outlet branch, K. Or, as shown in Fig. 78, these heaters frequently have baffles, or partitions, cast in the end chambers, which cause an increased length of flow of the juice through the tubes of the heater. The top chamber is usually fitted with an easily removable cover which is secured to it by hinged bolts, and a swinging arm

with hand wheel and screw, as shown at L, completes the arrangements for the quick removal of this top cover for cleaning purposes. In another type of juice-heater, styled for this reason "counter-current," the flow of juice and steam is so arranged by means of baffles that they run in

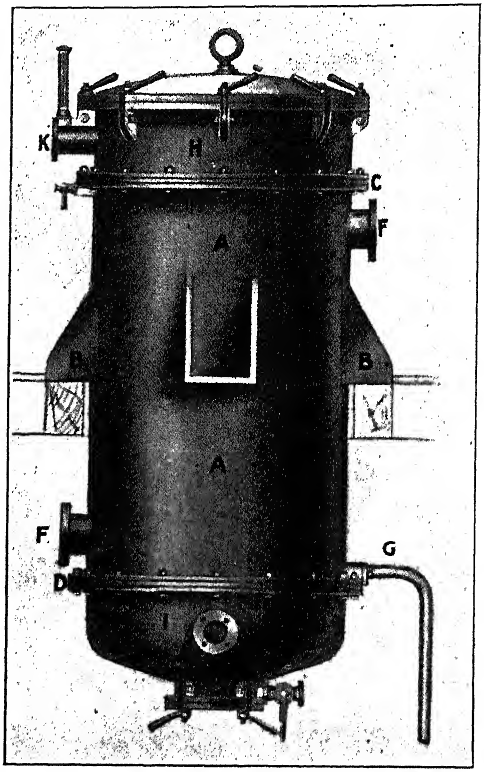


FIG. 76.—General external view of a vertical juice-heater.

opposite and circuitous directions. (See Fig. 78.) Such heaters may be of either the vertical or horizontal type, vertical heaters being preferable on the score of general convenience, greater facilities for cleaning, and for maintenance in good working order, but in either case they should preferably be constructed in such a manner as to ensure

a rapid circulation of the juice through a very limited number of tubes at a time, ensuring a maximum number of counter-circulations through any given heater.

In juice-heaters the temperature of the juice in some cases is raised to boiling-point, by means of exhaust steam

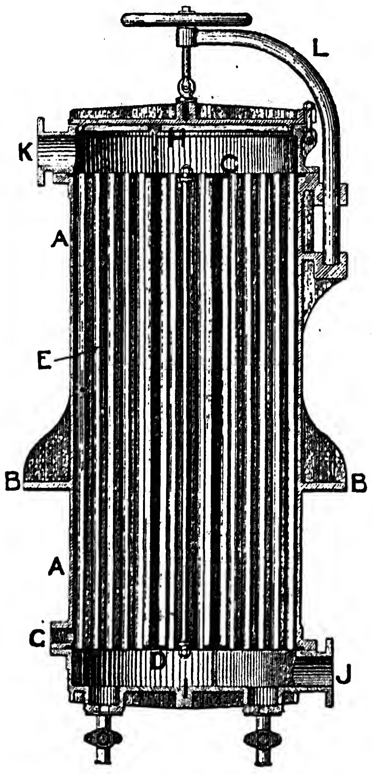


FIG. 77.—Section of a vertical juice-heater.

from the factory engines. In some factories, in order to secure a higher temperature than the atmospheric boiling-point, the juice-heater is placed on the ground floor, the head of juice in the discharge pipe being sufficient to give the necessary pressure. From the juice-heater the juice is delivered at a boiling temperature into the clarifying tanks

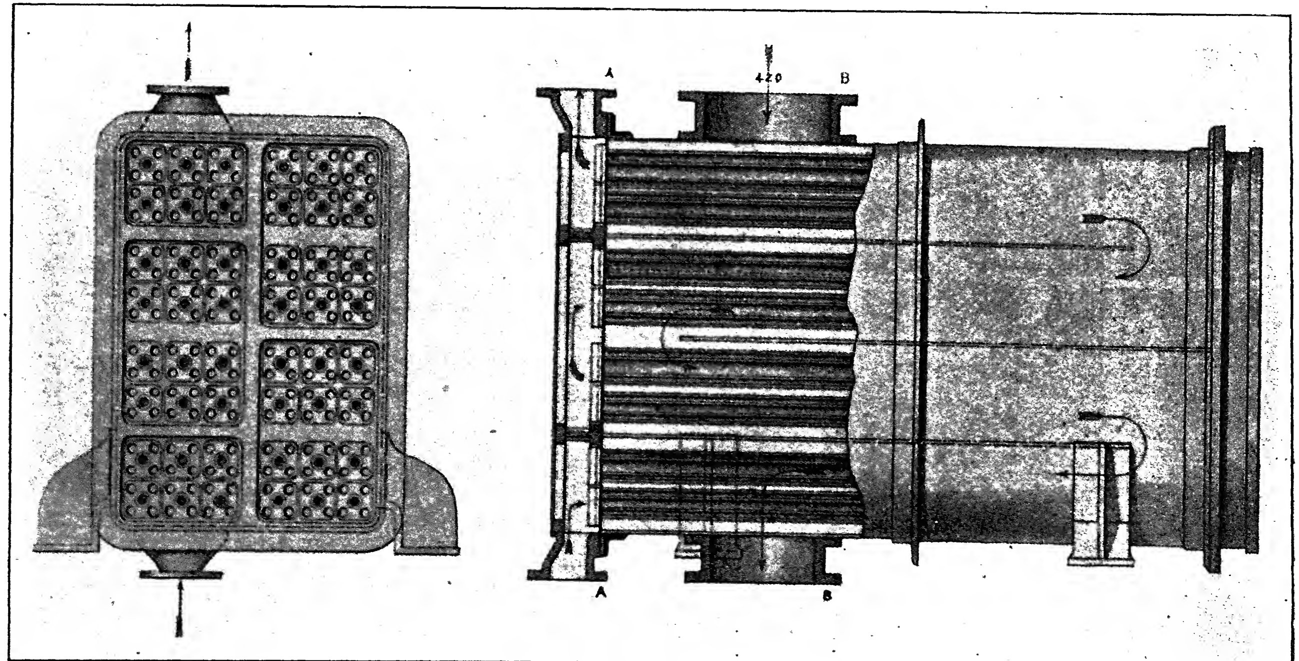


Fig. 78.—Counter-current juice-heater.

on an upper story, which consist of rectangular iron vessels of a capacity, as a rule, of from 700 to 1000 gallons. When the vessel is nearly full, the quantity of lime previously ascertained to be necessary is added, and the contents thoroughly stirred while the filling of the vessel is completed. The separated impurities are now allowed to subside, and after an hour or an hour and a half has elapsed

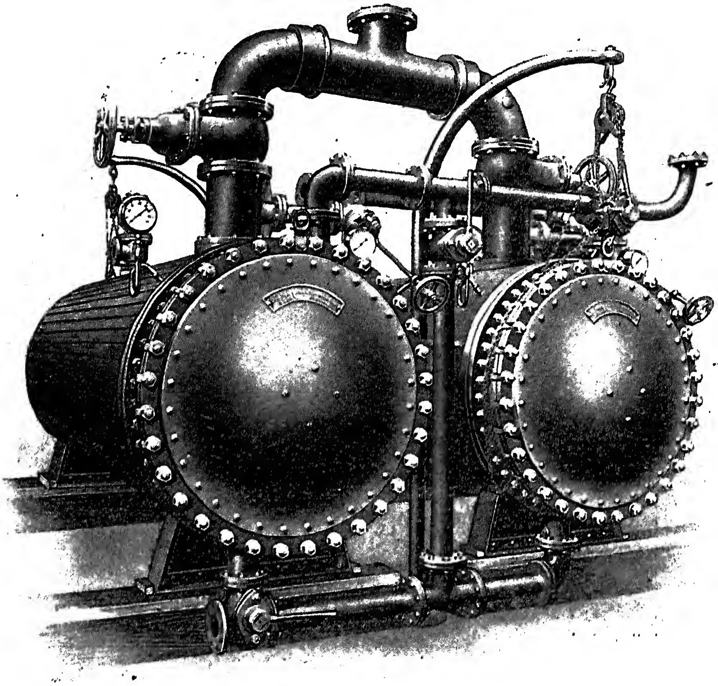


FIG. 78A.—Double arrangement of counter-current juice-heaters.

the clear supernatant liquor is drawn off for concentration. In this system, owing to the higher temperature at which the lime is added, and also to the fact that all air has been driven out of the juice before liming, the major portions of the impurities settle, instead of chiefly coming to the surface as with the French defecator. The "bottoms" of the

clarifying tanks are run off to the scum tanks, as with the latter. In some instances the lime is added to the juice as it leaves the mill, but this, although a simpler process than its addition in the clarifiers, is objectionable on account of the resulting interference with the work of the heater from fouling of the heating surface, although more satisfactory precipitation of impurities is claimed.

As with the French defecator, the determination of the proper quantity of lime to be used can only be fixed by experience. The manner in which the impurities subside when viewed in a test tube, and the appearance of the clarified juice in the upper part of it, afford the necessary guides. If in the limed and boiled juice the impurities present a flocculent appearance and subside with alacrity, the upper part of the deposit showing a convex appearance with a clear olive-green supernatant liquor, the clarification is adjudged satisfactory. It may here be remarked that juice apparently well clarified by the ordinary processes for refining-sugar making will always show further precipitation when boiled with more lime. It would, of course, be of advantage to secure this separation, but the effect of the excess of lime is so objectionable that in the ordinary processes the lesser evil of leaving the juice imperfectly freed from organic impurity is preferred. Probably not more than two-thirds of the possible separation is obtained under ordinary conditions, but in the double carbonatation system, to which reference is made later on, this difficulty is overcome, and practically complete elimination of organic impurity obtained.

In the above systems, the juice is heated to either slightly below, or up to, or slightly above the atmospheric boiling-point. A system of clarification has, however, been introduced in which the temperature of the limed juice is raised to 245° Fahr. or thereabouts, the latter being ulti-

mately heated under pressure in a closed vessel by high-pressure steam. This may be effected in a simplified form through the employment of strengthened heaters almost identical in design with those just described in connection with Figs. 76 and 77. The increased temperature, however, is ensured by arranging for the final and momentary application of high-pressure steam, and for the heated juice to pass from the heater under a given pressure instead of allowing it to overflow from it at the ordinary atmospheric pressure. One way of obtaining the required juice

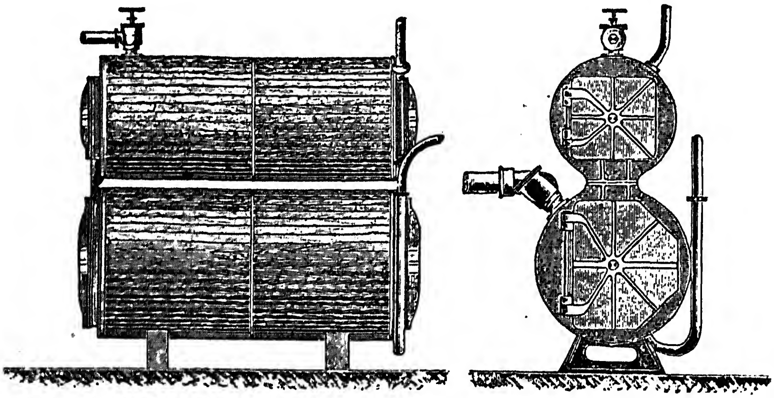


FIG. 79.—Side and end elevations of horizontal compound juice-heaters.

pressure is to place a loaded escape-valve on the outlet branch K, through which the juice has to be forced by the pump before it can escape from the heater, or, in another way, the latter can be placed at ground-floor level, and the outlet K can be turned upwards and extended to a height that will ensure the necessary static pressure. In either case an extra compressing force of some 14 to 15 lbs. per square inch must be arranged to act upon the escaping juice to ensure that it shall be heated to a temperature of 245° Fahr. in place of 212° Fahr.

A more elaborate method of obtaining the increase in

temperatures is shown in Fig. 79, which illustrates a system of compound juice-heaters. These consist of two cylindrical heaters, fixed horizontally one above the other. Low-pressure exhaust steam is employed to heat the lukewarm juice in the first or lower heater, whilst high-pressure steam is used in the upper and second heater to complete the process, the cane juice first entering the lower vessel and then passing upwards to and through the second heater.

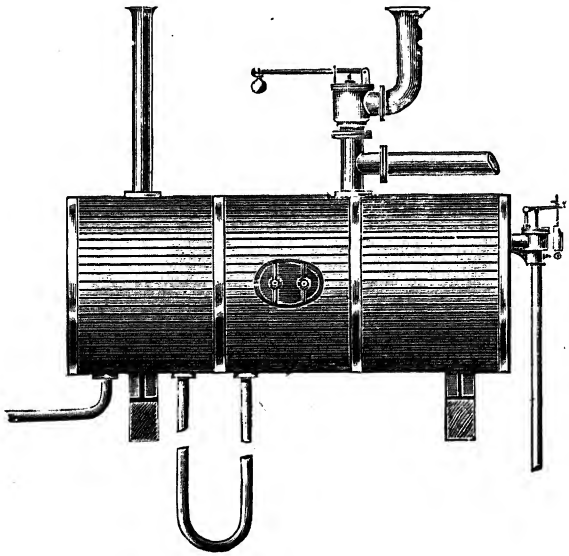


FIG. 80.—Elevation of separator used in connection with high-pressure juice-heaters.

As in the previous and simpler arrangement (Figs. 75 and 77), so also in this compound system, a loaded escape-valve regulates the compression of the treated juice, and thus ensures the attainment of the requisite higher temperature; and frequently the escaping juice is discharged into a separator, as shown in Fig. 80. By this arrangement the steam, which would otherwise flash-off from the super-heated juice into the atmosphere, is collected for use in one

or other of the evaporating vessels in the factory, thus effecting an appreciable economy in the process of concentra-

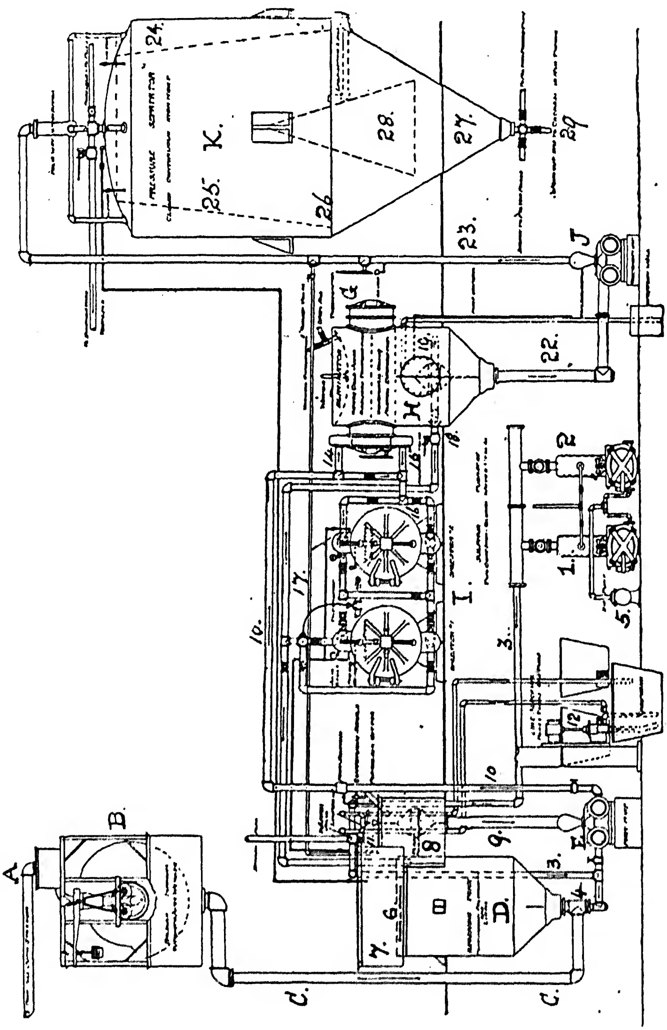


FIG. 81.—General arrangement of Deming's complete apparatus for effecting continuous clarification.

tion. It is claimed that more perfect coagulation of the separated impurities, besides greater separation, is obtained in this way. In this case the juice has carefully to be limed

to neutrality when cold. If made either acid or alkaline, the high temperature causes damage from inversion in the former and discoloration of the juice and production of objectionable products in the latter condition. After

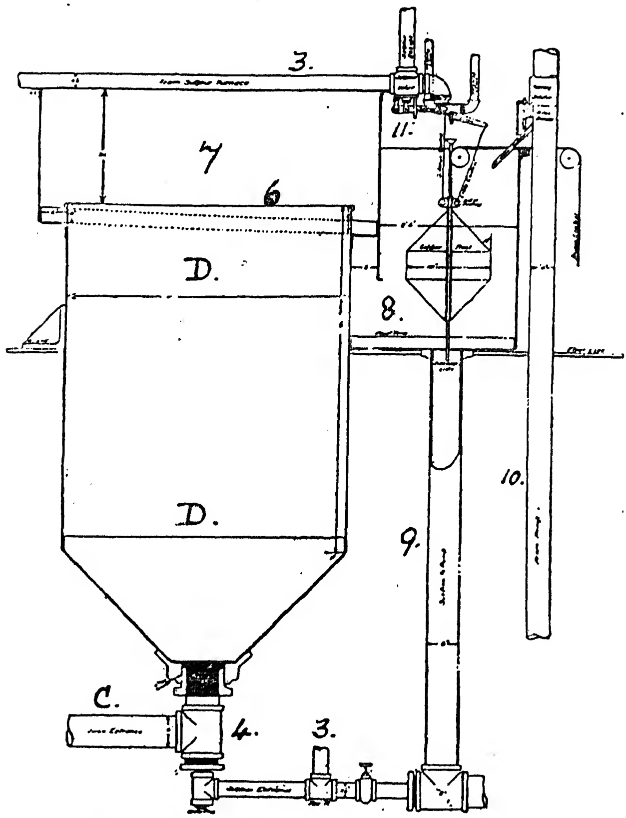


FIG. 82.—Sectional view of apparatus for effecting the continuous sulphuring and liming of the cane juice.

passing through the heater, the juice is discharged into receiving tanks and subsided.

In the above-mentioned systems, clarification is carried out with separate portions of juice. Processes are, however, extant in which a continuous flow of juice from mills

to evaporator takes place. In the Deming system of clarification, which is based on the subsidence principle, the limed juice, after being heated in a high-pressure heater, or system of heaters, is run through tanks in which subsidence takes place in transit. Fig. 81 furnishes a complete plan of the Deming apparatus, in which the juice from the cane-mills is led by a pipe or gutter to the point A, where it enters the automatic weighing machine, B, fitted with recording dials and juice samplers. Passing through this instrument, it is then taken by the pipe C to the continuous receiving tank D, which is usually of about 1000 gallons capacity. Fig. 82 gives an enlarged view of this tank, Fig. 83 showing it in conjunction with all its special accessories; and it is within the confines of this receiver that the cane juice is, if desired, sulphured.[1] Nos. 1 and 2 (Figs. 81, 82, 83 and 84) are the sulphur furnaces, the sulphur fumes being led away from them by the pipe 3, which conveys them to one of the inlets of the branched casting 4, fixed to the bottom of D. Here they are intimately mixed with the cold incoming cane juice which has been brought to the same point by the pipe C, the complete intermixture being facilitated by the action of the air-pump 5, which, assisted by the gravitation of the juice, forces both juice and sulphur into the receiving tank D, and maintains an agitation and circulation throughout the entire contents of the receiver in order to promote uniformity in the continuous sulphuring of the juice. As the vessel D becomes filled up to the brim 6 it overflows into the bottom of the upper extension tank 7, and thence into the pump-control box 8, where it is continuously limed as it enters the vertical suction-pipe 9 of the juice pump E,

[1] A fuller description of the sulphuring of cane juice is given in the account of the process of the manufacture of Demerara yellow crystals (see page 159).

taking the necessary lime along with it, the latter being thoroughly and uniformly mixed with the sulphured juice

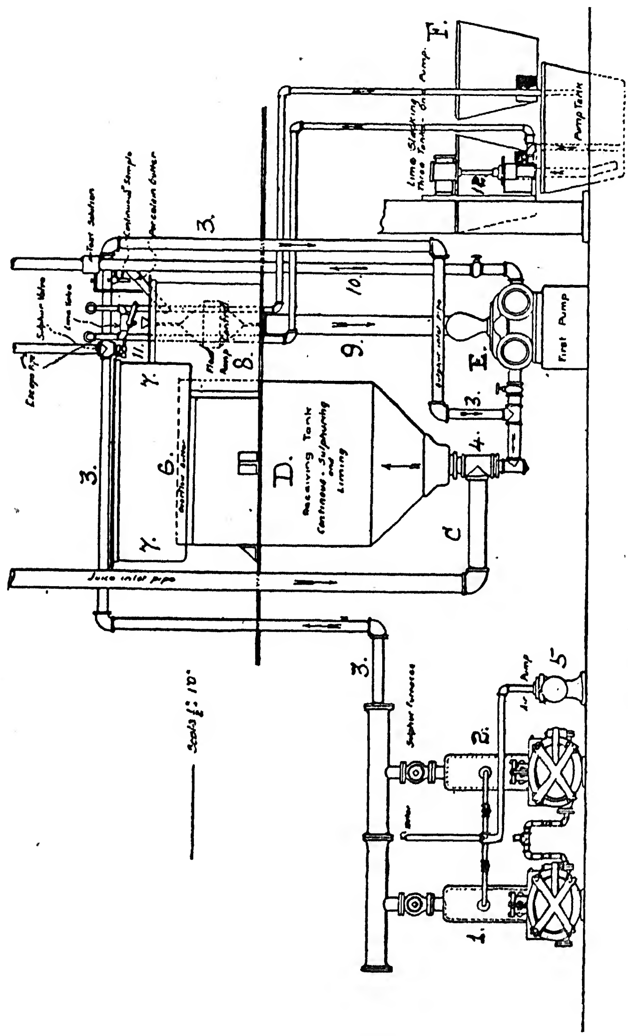


FIG. 83.—An extended view of the general arrangement of the various accessories used in connection with the sulphuring and liming of the cane juice, showing the receiving tank (Fig. No. 82) in connection with the sulphur furnaces and the apparatus used in the preparation of the milk of lime.

as the respective ingredients pass through the pump. From the discharge pipe 10 of this pump a small sample of the sulphured and limed juice flows continuously into a white

porcelain gutter, where it is joined by a constantly dropping testing solution. This solution records changes in colour, according to the amount of lime added, whereby the

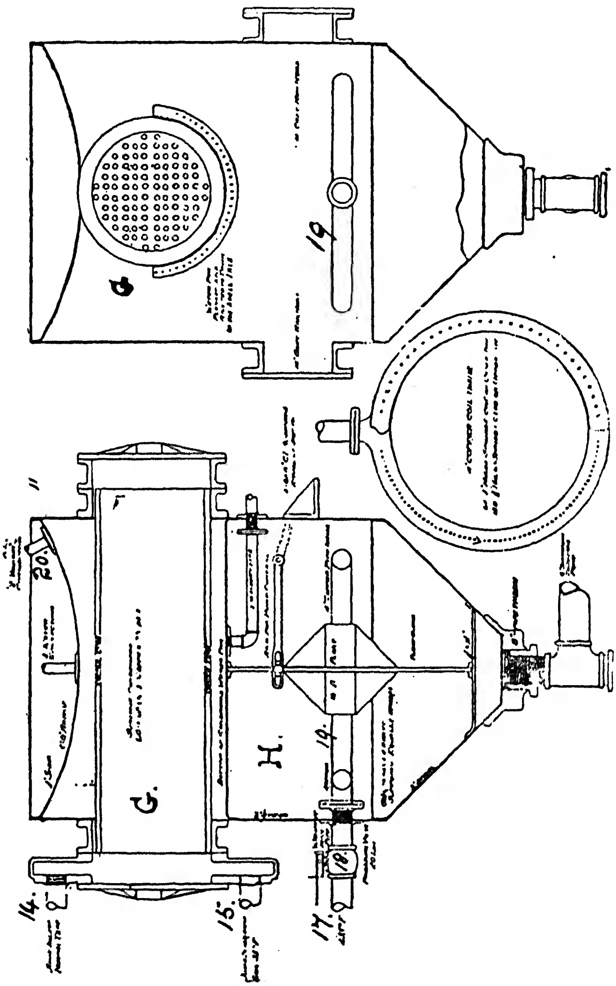


FIG. 84.—Two sectional views of the absorber and so-called eliminator, clearly showing the absorber G as arranged in combination with the eliminator H.

attendant determines the condition of the treated juice, any desired degree of acidity or alkalinity being uniformly maintained by a suitable manipulation of the lime-water

valve 11. This milk, or water of lime, is prepared in the three tanks seen at F, whence it is pumped up to 8 by the small pump 12, through the above regulating valve 11. The sulphured and limed juice now proceeds along the pump discharge pipe 10 to the absorber G. This absorber forms an extremely important section of the eliminator H, and the special combination of the two vessels G and H is clearly seen in Fig. 84. Here the juice absorbs an appreciable degree of heat from previously heated juice which has already reached the eliminator H from the digesters I (Fig. 81), and after passing through the absorber G it goes on to these digesters, where its temperature is raised to some 235° Fahr., under a juice compression of some 20 lbs. per square inch, maintained by a specially arranged pressure-valve. It should be noted that the juice enters the absorber at 14 and leaves it by the outlet branch 15, and joins the pipe system of the digesters at 16. These digesters are seen in Fig. 81, and are virtually high-pressure heaters which very closely resemble those already shown in Fig. 78, through the heating tubes of which the juice passes, and in which it is subjected to the transmission of heat administered by the high-pressure steam which surrounds the outer surfaces of the brass tubes in the bodies of the digesters. Leaving the digesters via the pipe 17, the juice reaches the aforementioned pressure-valve 18, and is thus set free to enter the body of the eliminator through the ring pipe 19. It should be remarked that the term "eliminator" is here applied in quite a different sense to that usually adopted, a special form of juice-cleansing vessel being commonly meant by it. A vacuum of some six or seven inches is supposed to be maintained in the body of this vessel by means of a connection to one of the adjacent factory condensers, and the released juice gives off a considerable volume of steam which acts upon the cold juice passing, as

already described, through the tubes of the absorber G. This steam is then condensed, and the hot water withdrawn approximately represents the amount of evaporation which has been effected by the foregoing apparatus. All indestructible gases liberated by the heat are instantly removed by the vacuum connection 20 (see Fig. 84), and another juice pump, J, is now employed to withdraw the juice from the eliminator through the discharge pipe 22 (Fig. 81), and force it through the pipe 23 into the closed pressure separators, K, which it enters entirely free of all gases. It is in the closed vessel K that the bulk of the impurities are finally separated from the treated juice, the latter entering it at the top of these settlers; the whole mixed mass being led into the annular space 24, which exists between the cylindrical side of K and the large suspended and truncated hollow cone 25. Passing downwards into the cone-shaped bottom of the separator by way of the lowest and narrowest opening 26 of the above annular spacing 24, it deposits all scum and sediment in the inverted conical bottom at 27; the smaller and second suspended cone 28 having for its object the duty of checking any tendency which the sediment may have to rise again into the upper portions of the separator. By these means all solids are left behind at 27, and the clarified liquor is collected within the interior of the larger cone 25, from which it is withdrawn through a wide trumpet-mouthed pipe, fixed high up within the cone, which leads it away to be concentrated. The process of separation is thus a continuous one, effected under constant pressure, and the continuously out-flowing and clarified liquor may, if so desired, enter the evaporator direct, and free of all gases, at an approximate temperature of some 190° Fahr. Similarly the accumulated mud, which has collected in the cone-shaped bottom of the separator, can be let out under

pressure from the bottom discharge pipe 29, and sent forward from there to the filter presses.

Another continuous system is based on the working principles of the French defecator (Fig. 73), already described, in which the passage of the juice is continuous

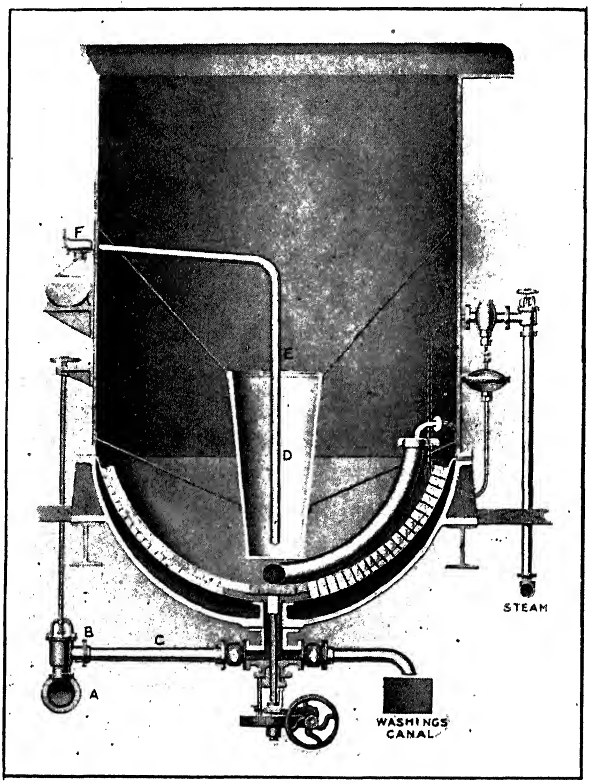


Fig. 85.—Hatton's continuous defecator.

in so far as each individual unit of it is concerned. Fig. 85 gives an interesting section of one of these units. The juice from the mill is limed cold to the degree desired and found most advantageous, and then flows in a constant and steady stream by the juice pipe A through the regulating cock B,

into the defecator by the pipe C, which delivers it to the bottom of the copper double bottom of the defecator. As the defecator fills up, the juice overflows and fills the vessel D, which is closed at the bottom. The juice then finds its way up the internal pipe E, and so away by the discharge branch F, into the clear defecated juice canal, whence it passes direct to the supply tanks feeding the evaporator. If it is desired to treat the raw juice with sulphurous acid, this can be done by means of either of the sulphuring arrangements mentioned below. The scums form, as they rise, a thick layer on the top of the liquid, while the juice flows over the edge of the vessel D to the bottom thereof, ascending the internal pipe and going away from the defecator in a clear state. Although the temperature never exceeds 210° Fahr., the scums become comparatively dry and are pushed up several inches above the rim without overflowing, being removed from time to time as they collect. Any matter which might be precipitated during the process, and might fall to the bottom, would, if left there, interfere with the heating efficiency of the copper bottom. This is therefore removed once in twelve hours by gently revolving the scraper, and so loosening the incrustation, and then suddenly opening the bottom discharge cock for a moment, allowing the rush of liquor to carry out the deposit; thus the defecator, under these conditions, can work continuously for several days and nights. Fig. 86 shows a battery of these defecators, as they would be used in a sugar factory. It will be of interest here to emphasise the characteristic difference between the above two continuous systems which have just been described. In the case of the Deming system, clarification of the treated cane juice is attained through the precipitation of the various impurities; whereas Hatton's apparatus is so arranged and manipulated as to cause the same class of feculences to rise

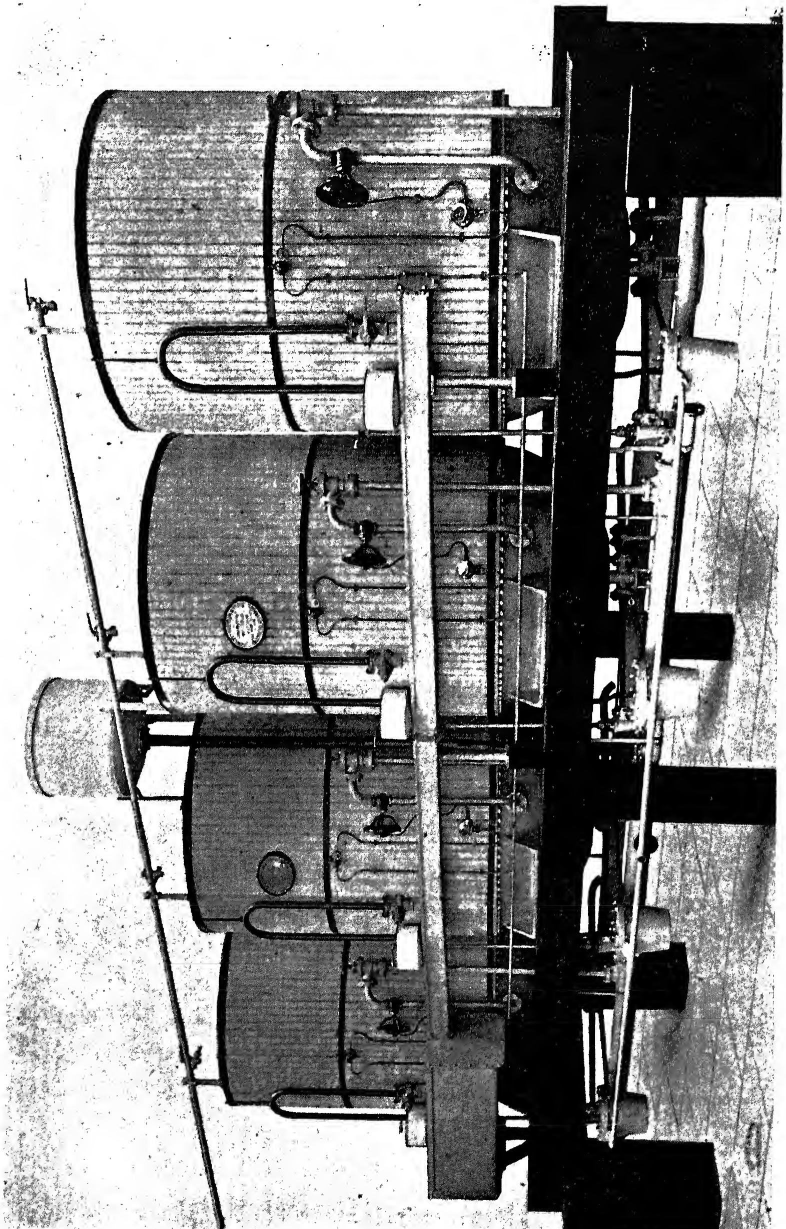


FIG. 86.—General view of a battery of Hatton's defecators.

and float upon the surface of the clarified liquor. The act of clarification, as a matter of actual fact, takes place in opposite directions, the one upwards and the other downwards, but with similar results.

In Mauritius an auxiliary continuous system is occasionally in operation in which the sulphured juice is made to run along narrow channels formed by partitions some 12 inches high in a wide shallow tank. At the alternate end of each channel, about a foot of the partition is slightly cut away so as to allow of overflow into the next, the whole forming a conduit of some 200 feet in length. The impurities subside *en route*, and a considerable scum forms a blanket on the surface, and a fairly clear sulphured juice results, which goes forward for further treatment.

There are still a few factories making refining vacuum-pan sugar, in which the bulk of the evaporation is done in the open by "copper walls." In these, after the ordinary clarification, the juice undergoes a further cleaning as it passes through the coppers, as with muscovado sugar. In some cases, also, where evaporation is by multiple-effect, and the juice is particularly impure, "eliminators," as described below, are used in addition to the ordinary clarifiers.

(3) For Demerara yellow crystals. In the make of that variety of sugar called Demerara crystals, the system of clarification adopted for the manufacture of refining sugar has to be considerably modified and extended. The object aimed at is to produce a fairly high polarising sugar of a delicate canary yellow colour, pleasing to the eye as well as to the taste and smell. To carry this into effect the physical characteristics of the cane juice have to be preserved carefully. The first step in the process is to subject the cold juice to the action of sulphurous acid gas, scientifically known as sulphur dioxide. This is usually done by

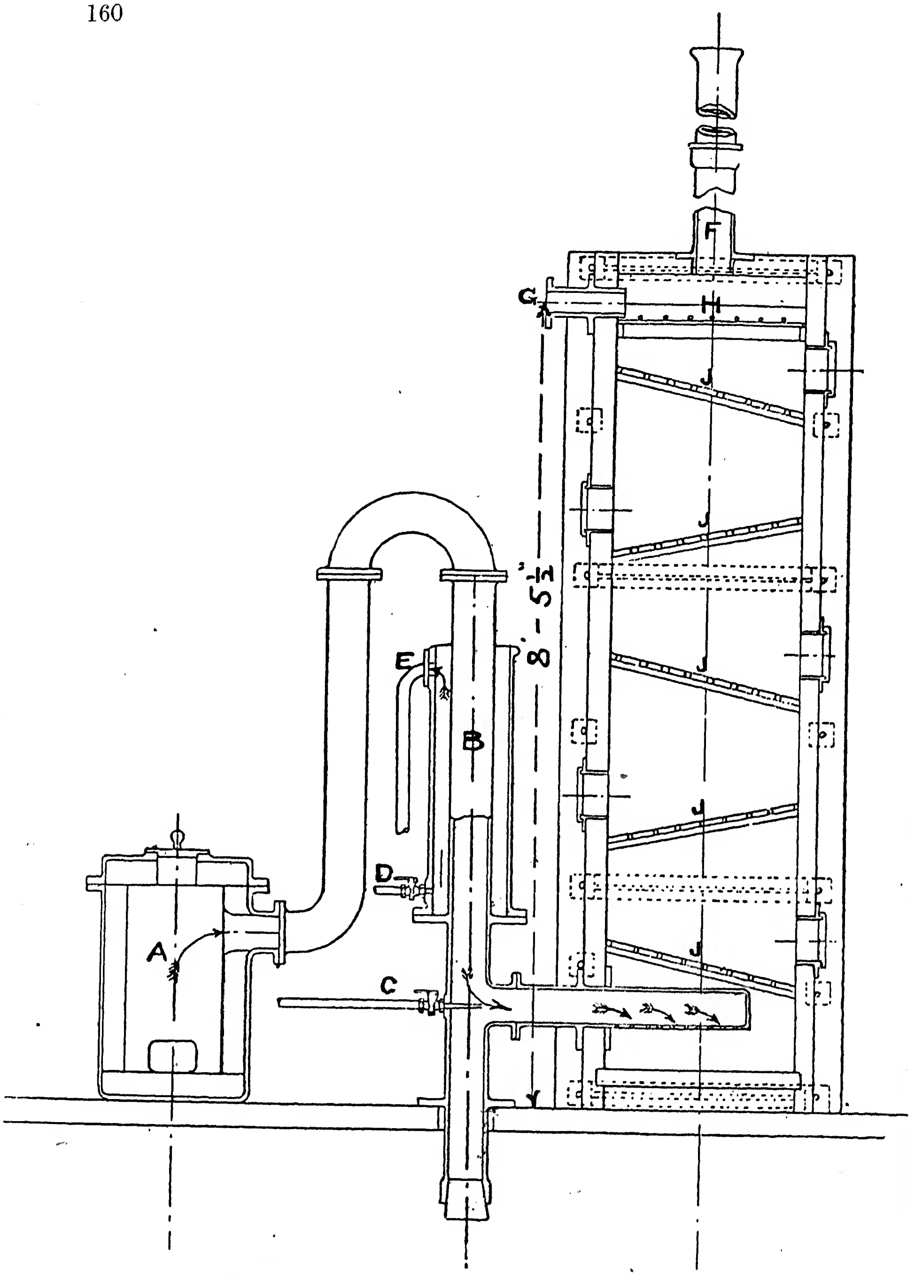


FIG. 87.—Sectional view of sulphur box with its attached sulphur furnace.

means of what is known as a "sulphur box." This consists of a wooden rectangular tower of suitable dimensions (Fig. 87), the latter varying greatly according to the special requirements of various localities. The height of this tower will be found to range from 6 to 12 feet, whilst the rectangular area is arranged to permit of the free passage of the full volume of the shower of juice which has to be sulphured. The cold juice from the mill enters at the top of the tower by the pipe G, whilst the sulphur gas is generated in a simple form of furnace seen at A, and enters the box at the bottom by the pipe B, under a moderate pressure promoted by the steam jet C, the two substances travelling in opposite directions and thoroughly intermixing with each other. The gas can be cooled by water as shown at D, E, and in order that the sulphur may have the fullest opportunity of acting effectively upon the juice, the latter in its downward passage is broken up as much as possible by the trays or breakers H, J, which are fixed at frequent intervals within the tower, and throw the falling juice into a shower. When the latter has reached the bottom of the tower, it leaves it through a trapped pipe not visible in the illustration, and proceeds to the heater.

A more elaborate but very efficient sulphuring apparatus assumes the form of a sulphur churn, as shown in Fig. 88. Here A is a horizontal cast-iron cylinder of, say, 10 feet internal length by 3 feet diameter, within which a system of revolving scoops or paddles makes some dozen revolutions per minute. The cold cane juice enters A through the inlet C, and, passing through the churn, emerges at the outlet which is situated at the opposite end of the vessel. In the course of its passage, however, its progress is interrupted by the action of the revolving scoops F, which toss it about in an effective manner, and so subject it to the action of the sulphur gas which enters the churn at D,

and after efficiently performing its duties escapes by the chimney seen at H.

In some cases again the cold juice is collected in suitable tanks, at the bottom of which a system of perforated pipes is fixed through which the sulphur gas is forced by means of an air-pump. The gas thus agitates and permeates the

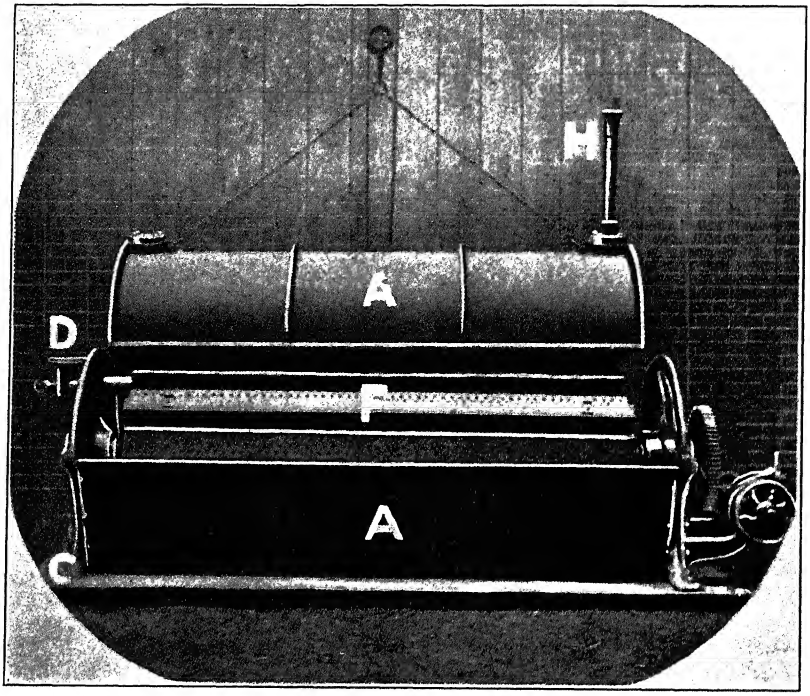


FIG. 88.—Longitudinal elevation of sulphur churn. The upper half of the cylindrical casing is lifted away from the lower half, in order to show the revolving scoops and puddles which toss the cane juice about within the churn.

body of the contained juice. In each of these kinds of apparatus, which may assume a variety of modified forms, the chief object is one and the same, namely to enable the minimum amount of sulphur to act in the most efficient manner possible upon the maximum quantity of cane juice; and in its passage through either of the foregoing con-

trivances the juice comes in contact with a current of air which has become charged with sulphurous acid gas by passing over burning sulphur in the furnace. This gas, very soluble in water, is absorbed by the juice, which becomes strongly acid. The effect of this is to change the colour of the juice to a milky yellow, while at the same time a certain amount of precipitation takes place. This change is not caused by bleaching proper, but is chiefly the result of the acidification. As already mentioned, if cane juice is allowed to become sour spontaneously, or if an acid, not a bleaching agent, be added, a very similar effect is produced.

If, however, the action of the sulphurous acid were only this, subsequent treatment with lime would reproduce the original condition, and there would be no object in the use of the former. There is, therefore, evidently some distinct action apart from this, and it is probable that the useful effect of sulphuring is due to the introduction thereby into the juice of this powerful reducing agent, which counteracts the tendency which juice possesses of being darkened by oxidation during clarification and concentration. In other words, although the actual change of colour is due merely to acidification, the presence of sulphites in the juice bleaches it in the negative sense of preserving it from being darkened from oxidation. It is claimed, also, that the use of sulphurous acid has the effect of materially assisting the crystallisation of the sugar by its action upon the gummy bodies present.

After being "sulphured" the juice passes through a juice-heater of the ordinary type, where the temperature is raised to about 212° Fahr. Care has to be taken to avoid excess in sulphuring, as otherwise inversion—or loss of cane sugar from conversion into uncrystallisable sugar—is likely to take place. The acidity of juice thus sulphured is

not due, within ordinary limits, to free sulphurous acid, which has a strong inversive power, but to organic acids originally present in the juice in the form of salts, of soda, and potash. Sulphites of the latter basis are produced, and the organic acids liberated. Unless, therefore, the sulphurous acid has been absorbed in excessive quantity, the acidity induced is merely due to the weaker organic acids. The effect of these at a boiling temperature is, however,

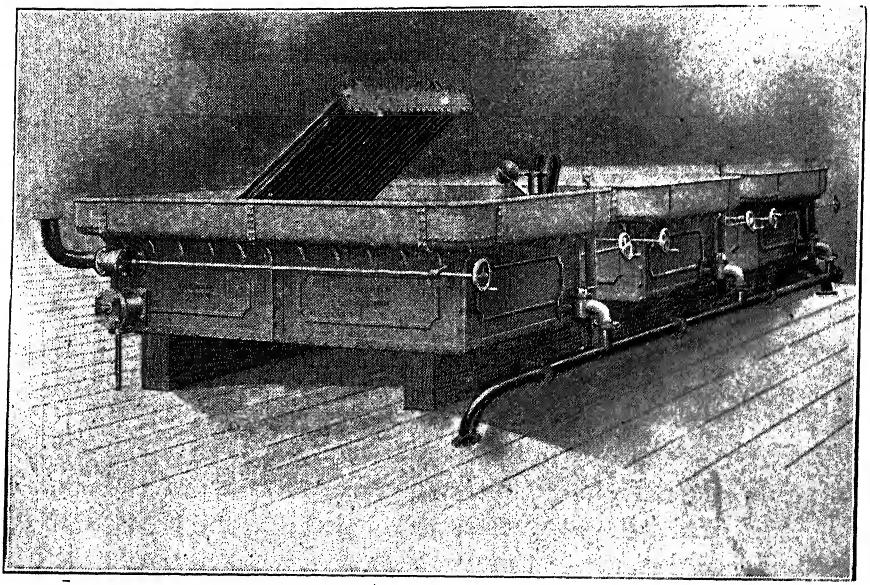


FIG. 89.—A battery of rectangular eliminators.

quite sufficient to cause some loss from inversion, if the sulphuring has been done to too great an extent.

The juice as it comes boiling from the juice-heater goes to the subsiding tanks, where lime is added as already described under the heading of Refining Sugar. The point of clarification aimed at is slightly short of neutrality, a

run off to the eliminators. The latter may be of either rectangular or circular form, and Figs. 89, 90, and 91 show the rectangular, whilst Figs. 92 and 93 give particulars of the circular apparatus. Referring to the first three illustrations, it is seen that rectangular eliminators closely resemble the ordinary clarifiers described in Figs. 74 and 75. They are usually, however, of greater depth and capable of holding a larger quantity of liquor; and they are, in most

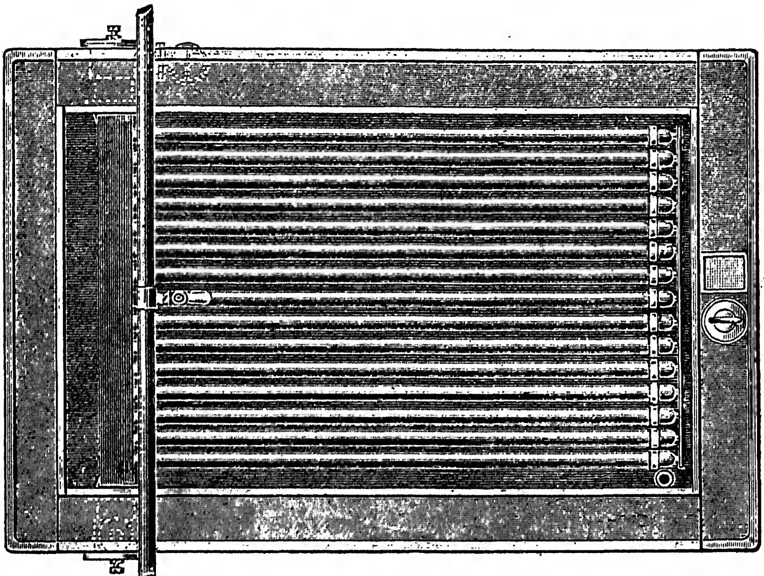


FIG. 90.—Plan of a rectangular eliminator.

cases, specially fitted with a large upper gutter which surrounds the entire rim of the vessel, besides being also furnished with ball-floats and attached swivelling pipes for the purpose of withdrawing the clear liquor. The surrounding gutter is more clearly seen in Fig. 90, whilst one of the ball-floats and pipes is seen in its highest position in the right-hand corner of the nearest unit of the battery of eliminators shown in Fig. 89.

rectangular ones, save as regards such points as have to be modified to harmonise with their rounded contours. Thus the continuous gutter circles around the upper periphery of the curved sides, and the heating surface has to be formed of fixed coiled pipes (Fig. 93) in place of removable nests of straight tubes. In other respects the attendant would turn from the service of the one form to the superintendence of the other without, so to speak, being conscious of any vital alteration of surrounding conditions. Both systems may be arranged so as to be equally convenient and possibly

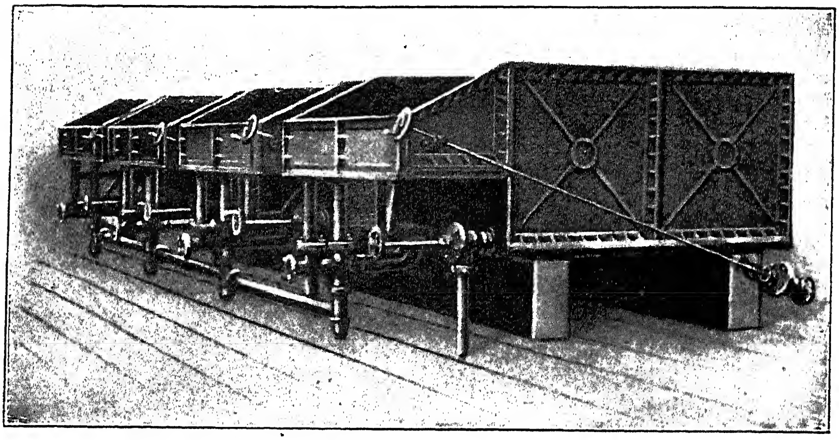


FIG. 91.—Special form of rectangular eliminators.

equally efficient too, and it may be left to the individual taste to determine which style is to be selected for use in any given factory.

The rectangular eliminators, however, in Fig. 91 possess distinctive features which have for their object the attainment of a continuous and automatic clearance of the scums from the surface of the boiling liquor. Instead of the latter being left to boil indiscriminately, thus throwing the scum into any or all sections of the peripheral gutter, a definite upper surface current is given to the mass of the

contents which tends to throw forward all the floating impurities into the broad overhanging double gutter, which is plainly seen in the illustration. An adjacent hand-wheel and spindle control the steam supply to the customary heating surface, and the attendant can remain in front of these vessels.

The eliminators having been sufficiently filled with juice, phosphoric acid is added, usually in the form of a solution of concentrated superphosphate of lime. The green colour of the juice is at once changed to a light orange

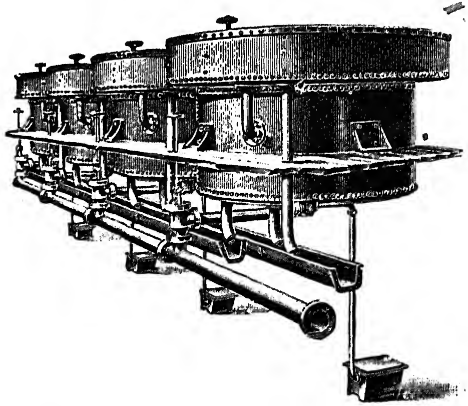


FIG. 92.—Battery of circular eliminators.

or canary yellow. Steam is then turned on, and a dirty white scum rises which is removed by skimming. As the juice approaches the boiling-point it foams up, and the remainder of the scum is removed by "brushing." In fact, the treatment in the eliminators reproduces under more favourable conditions the cleansing process of the copper wall. The operation of clarification is now complete, although in some factories the syrup after concentration is again passed through a sulphur box, an operation which is a great assistance in obtaining the desired final colour.

The object of the addition of phosphoric acid is to change the green colour which remains in the juice, by reason of the under tempering, into yellow, which it does by liberating the colouring matter from its combination with the bases in the juice. Before the substitution of multiple evaporation for the open copper wall, the high concentration of the already rather acid juice led to the production of further acidity and consequent change in colour to yellow, thus doing away with the necessity for added acid at this stage. The production of this acidity,

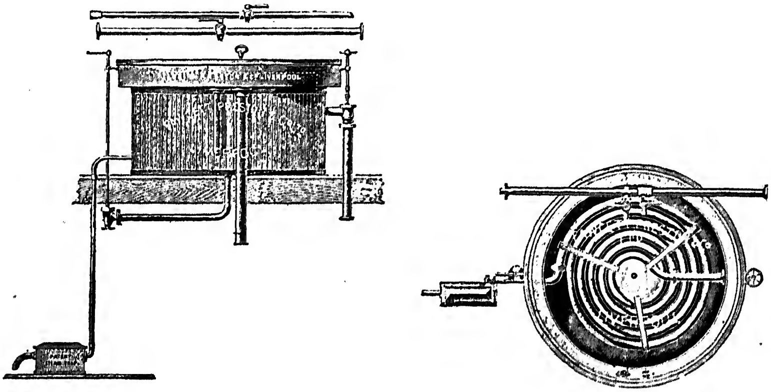


FIG. 93.—Plan and elevation of circular eliminators.

however, was obtained at the cost of sugar. Should the juice be over tempered in clarification, a greenish-grey, instead of a yellow, sugar results, a colour which no subsequent treatment with phosphoric acid will rectify. In fact, the principle which underlies the process is that of working, except during the time which the juice spends in the clarifying tanks, with a strongly acid juice. The greatest care has consequently to be exercised throughout the process to secure a minimum of loss from destruction of cane sugar by inversion. With the employment of suitable evaporators and sound juice the loss should not amount to more

than 1 or 2 per cent. from this cause, but the larger proportion of impurities introduced into the juice by multiple milling and maceration has brought about conditions which seriously prejudice the manufacture of this kind of sugar. Under modern conditions of milling, it is, in fact, frequently easier to make white sugar than a high class of yellow. This system of clarification for Demerara sugars entails considerable expense, not only owing to the cost of chemicals, but also to the great wear and tear of pumps, juice-heaters, and evaporator tubes through corrosion by the volatile and non-volatile organic acids liberated in the juice.

(4) Clarification for White Sugar. The process adopted for the manufacture of white sugar is usually what is known as the sulphitation process, although in some instances the double carbonatation system is employed. The sulphitation method of clarification is based on the use of large quantities of sulphur in the form of sulphurous acid with the employment of a proportionate quantity of lime. The effect of the sulphite of lime thus formed is, in the first place, to keep the juice in a state of reduction, thus preventing oxidation and darkening; in the second, to precipitate freely the gums and albuminous bodies; and in the third, to assist the operation of the filters by the admixture with the scum cake of sulphite of lime crystals.

In the process as generally applied, the juice as it comes from the mills is very thoroughly strained. It is then transferred to the liming tanks, where it is treated with milk of lime in large quantities, varying with the nature of the juice, as much as $1\frac{1}{2}$ gallons of a density of 15° Bé sometimes being required for 1000 gallons of juice over and above that required to neutralise the natural acidity of the juice. The effect of the large quantity of lime is to separate very thoroughly the gums and the albuminous

impurities. It is customary, in order to facilitate this operation, to heat the juice to about 152° Fahr. before the addition of the lime.

After thorough admixture with the lime, the juice is sent on to the sulphitation tanks, where sulphurous acid gas, derived from the burning of sulphur, is forced into it, until a slight but fixed degree of acidity is produced.

The sulphured juice is now passed on to the juice-heaters, where the temperature is raised either to the atmospheric boiling point or to a few degrees above, although nothing is gained by the latter. From the juice-heaters the juice emerges and is transferred to the subsiding vessels. There it is allowed to subside for from two to two and a half hours; on account of the large amount of lime used in the clarification, there is a large quantity of "bottoms," and a longer time is thus required for subsidence than with the manufacture of refining sugar.

The clear supernatant juice from the subsiders is now passed on to the supply tanks of the evaporator, while the bottoms go to filter press tanks. Here they are blown up and resubsided, and the bottoms from these sent to the filter presses. The clear liquor from the filter press tanks and from the presses goes directly to the evaporator supply tanks.

Where a continuous sulphur apparatus is employed, it is advisable to sulphur the juice as it comes from the mill, liming coming as the second operation in clarification instead of the first. It is a primary objective in white sugar manufacture that the details of the clarification process should be carefully attended to. One of these details is the accurate obtaining of the neutral reaction of the juice. This process is not so easily carried out when the sulphuring comes after the liming with a continuous sulphuring apparatus as with sulphuring in tanks.

From a clarification point of view—that is to say, with the object of the more complete removal of the gums and other impurities—liming as the first operation is the natural course. The heavy alkaline reaction means a very substantial removal of impurities, especially of gums, and it can be readily understood that it is better to obtain this reaction and subsequently neutralise it with the acid, than to acidify and subsequently neutralise it with lime.

A further advantage is gained by there being no risk of a false appearance of neutrality in the juice from the milk of lime containing particles of lime which escape solution until the juice is heated. Juice going to the heater may appear to be neutral and subsequently appear alkaline in the subsiding vessels. Heating the juice to 150° Fahr. before liming secures an absence of this danger, but it is essential that this temperature be not exceeded as the doing so would lead to its irrecoverable darkening from the formation of glucates by the action of the lime on the glucose.

A modification of the above process is that devised by Bach. In this only sufficient lime and sulphur are employed, in the first instances, to secure an ordinary clarification, the balance being applied to the syrup. As the latter comes from the evaporator, it is treated with the bulk of the lime and sulphur, raised to the boil, and filtered through filter presses. Filtration takes place very easily on account of a large quantity of sulphite of lime crystals becoming insoluble, and thus aiding filtration more than with the thin juice. A very bright and colourless syrup results.

Too great stress cannot be laid on the necessity for careful control of each step in clarification for the manufacture of white sugar by the sulphitation process. There is no room for slip or error, and the juice itself should be carefully watched so that any change in its character may

be seen and the necessary alterations made in liming and sulphuring.

The other process by which white sugar is manufactured, but which is also used in the make of refining crystals, is that of double carbonatation. The object of this process is to secure all the good effects of heavy liming in removing organic impurity, and at the same time to avoid the trouble arising from the use of large quantities of lime in the presence of uncrystallisable sugar when the juice is subjected to a high temperature. In this process the juice is limed very heavily—as much as 1 per cent. to $1\frac{1}{2}$ per cent. of the weight of canes of temper lime being added to it—at a temperature of 140° Fahr. Carbonic acid is then pumped through it until the alkalinity is reduced to a specific point, and the whole is filtered through filter presses. The clear liquor obtained is then raised to the boiling-point, saturated with carbonic acid, boiled for a few minutes to drive off the excess of carbonic acid, and again filtered.

The theory of this process is that the objectionable lime compounds formed with the uncrystallisable sugar, being insoluble in a faintly alkaline solution at temperatures below 140° Fahr., are separated with the first precipitate. The maximum separation of albuminous matter and gums is also effected by the use of large quantities of lime. The process, however, is an expensive one, owing to the double filtration necessary and the high cost of lime, and can only be used where a supply of lime-stone is readily available. The process involves, too, the loss of the glucose, an important factor in rum or cattle-food making.

The above comprise the ordinary methods of clarification in use in sugar-cane factories. Processes involving the adoption of tannin and alumina in various forms have been introduced, but they have generally failed through the

results gained not being commensurate with the cost of materials. In the manufacture of a cheap commodity like sugar, there is no margin for expensive processes of clarification, and the use of lime, save for special makes of sugar, has up to now answered all the purposes of economic extraction. It may be remarked, also, that a system of clarification has to be adapted to the nature of the juice to be worked. Thus the thin juices of Demerara suit the subsidence systems better than the denser juices of Hawaii, although maceration has done much to do away with this distinction.

Lead has been used in clarification in Scoffern's process, the excess being removed as sulphite, but the poisonous nature of this agent led to the process being abandoned. Père Labat also mentions antimony as being used in the French islands at the beginning of the eighteenth century for the manufacture of raw muscovadoes.

CHAPTER VI

FILTRATION

AFTER the juice has been treated in the clarifiers, the clear portion of it, as a general rule, passes, as has already been mentioned, either to the eliminators or straight to the evaporators, according to the make of sugar or the extent of impurity of the juice. The muddy deposits in the clarifier tanks, or the scum which has risen to the surface, according to the system of clarification employed, together with the impurities separated in the eliminators, are now run into rectangular iron vessels which are fitted with coils for steam-heating. To the contents of these, lime is added and steam applied in the coils until a boiling temperature is reached. After a few minutes' boiling the steam is shut off, and, after subsidence for an hour or so, a further quantity of clear liquor is drawn off, to be sent either to the eliminators for further treatment, or direct to the supply tanks of the evaporator. The thick muddy residue remaining, which should represent the impurities separated from the juice, together with lime, from the clarification, is again skimmed, and then sent to the filter presses, it being of the greatest importance that a high temperature be maintained at this stage. Figs. 94, 95, and 96 show different forms as well as various details of these presses. The last two figures are taken from opposite points of view, so that the entire contour and arrangement of the apparatus may be clearly understood. In Fig. 95 the press is shown firmly closed and ready for work, but in Fig. 96 the machine

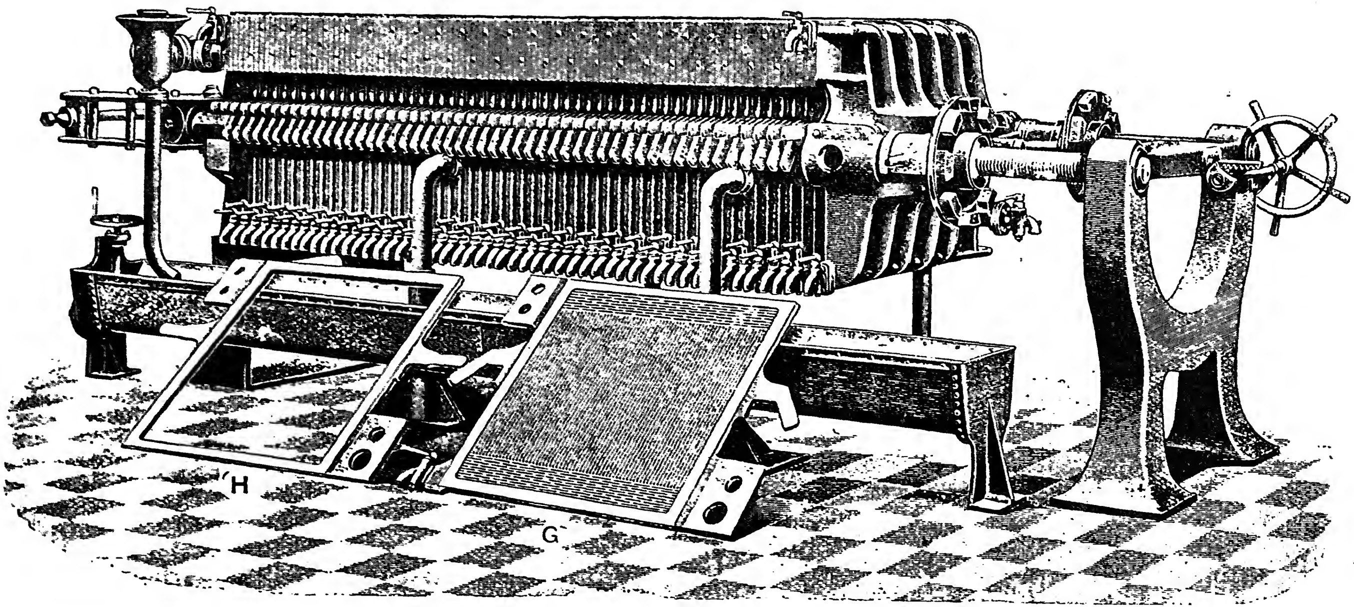


Fig. 94.—Filter press.

is, on the other hand, slacked off and open, just as would be the case for cleaning and for the renewal of the cloths. The framework of all these presses, however much the shape and details may vary, consists of two very strong cast-iron standards, A and B (Fig. 96), of which A merely acts as a frame standard, whilst B is combined with the massive backing-plate, C, corresponding with the similar and separate compression-plate, D, which forms the other outer end of the press proper. A and B C are connected together by powerful frame-bolts or stay-bars F (Fig. 95), which carry the plates or frames, G and H, which form the

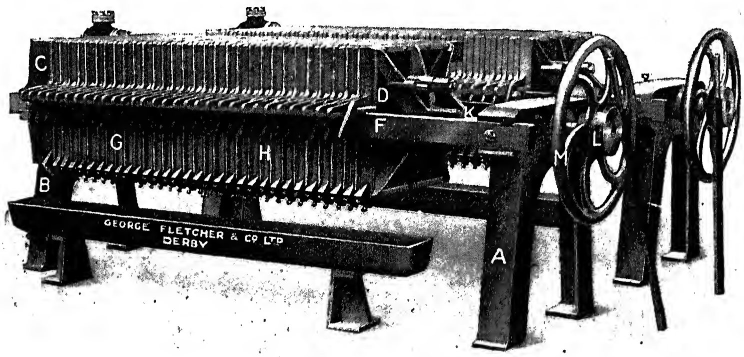


FIG. 95.—Filter press closed for work.

body of the machine. These plates and frames hang or sit upon the connections F, which are of sufficient strength both to support the weight of the former without sagging, and to withstand the tensile strain thrown upon them by the compression of the frames whilst the press is at work. The arrangement of the bodies of these machines is usually as follows: D and C (Fig. 96) are massive solid plates with certain apertures or ducts cast in them, and their inner surfaces are ribbed. Next to them an open frame, H, is placed, and next to H a solid plate G, ribbed on both sides. Then another frame H, followed again by another solid

plate G, and so on, until the complete installation of some twenty plates and nineteen frames is in place. Before the plates and frames are forced together, suitably shaped pieces of filter-cloth are thrown saddle-fashion over each of the solid plates G, and they are so disposed that they cover their entire side surfaces, D and C alone requiring special half-length strips for their inner surfaces. The plates, frames, and cloths are then forced together with a total

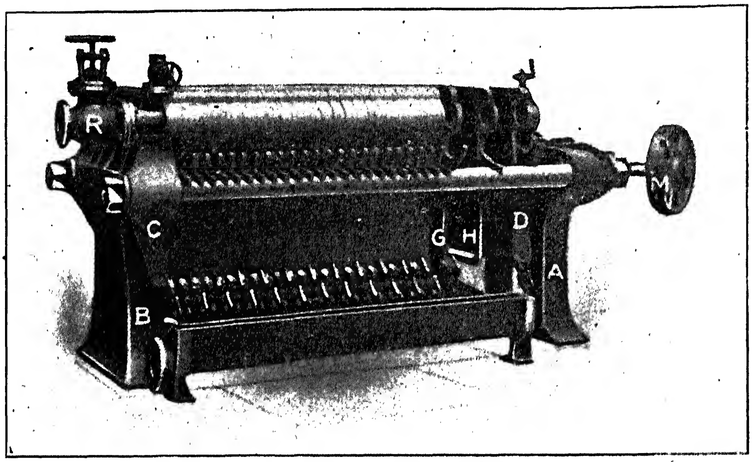


FIG. 96.—Filter press opened for cleaning.

pressure measured in tons, through the agency of the powerful screw K (Fig. 95), which is turned by long levers inserted temporarily in the slots L of the tightening-wheels M. As the press stands ready for work, it is made up as follows: first are the plates D and C (Fig. 96), then their strips of filter-cloth, next the frames H, then filter-cloth. Up against the latter come the plates or leaves G, then more filter-cloth, and so on in regular rotation until the main framework of the press is sufficiently full to do the maximum amount of work which may be reasonably looked for, and yet leave a suitable amount of clearance between the leaves

and the end frame, as will facilitate the opening of the press and cleaning of the cloths without having to lift any of the plates out of the main frame.

At the upper right-hand corner of the leaves and frames, in this illustration, will be seen fairly-sized circular openings through which the unfiltered juice enters the press, via the regulating valve R. In these holes, in the frames H, will be noticed through-fare passages which lead the incoming juice into the vacant rectangular chamber formed by the rim of these frames. The mud is thus retained in these chambers whilst the juice filters through the cloths on to the ribbed surfaces of the leaves. It then passes through small holes in the latter which communicate with one range of the alternately placed sets of taps, through which it escapes out of the filter into the juice trough. The circular openings in the leaves G are larger than those in the frames H. They are plain holes, into which vulcanised rubber sleeves are firmly fixed which form the conduit joints between the frames and plates.

Similarly, smaller holes are seen close to the larger holes, previously mentioned, which in turn communicate with certain passages in the leaves G, and are the means of introducing steam or water to the reverse side of the cloths, so that, when the juice is temporarily shut off, a reverse current of steam or water can be employed to clear the cloths and retained mud of any remaining traces of sugar which may be left in them. This sweet water issues from the press through the other set of alternate taps, and the institution of this reverse current is an important feature of filter-press construction, enabling, as it does, the press to be kept at work for a greater length of time without changing the cloths than would otherwise be possible, besides tending to secure a more thorough voidance of sugar which would have been wasted in the cloths and residual mud without

its assistance. Various modifications of the positions and sizes of all the above passages and spaces are to be found in different makes of presses. Sometimes the juice and water openings are respectively situated in diagonally opposite corners of the press leaves, but the controlling principles of efficient filtration remain the same, whichever disposal of the details may be instituted or effected by varying ingenious devices of minor importance.

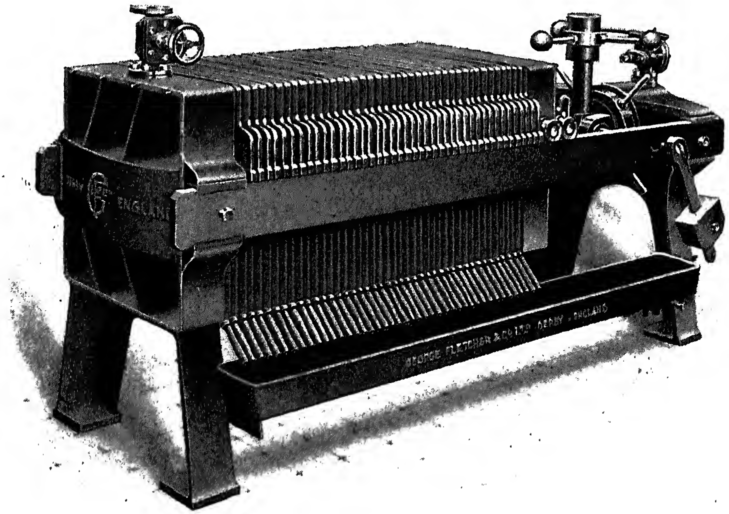


FIG. 96A.—Filter press fitted with patent hydraulic closing gear.

When the press-frames H have become filled with a firm and well-washed cake of residual sediment, they are thrown open, as shown in Fig. 96. The mud-cake falls off the cloth surfaces and drops into suitable receptacles placed beneath the floor of the press-room. The press can then be closed again, and the cloths (after again being washed and steamed by reverse current) used afresh without actual changing, or another lot of the latter can be put in position whilst the dirty set are sent to be cleansed.

Filter presses are sometimes closed and held under hydraulic pressure, as shown in Fig. 96A. This form of applied pressure takes the place of screw-pressure as shown in Fig. 96.

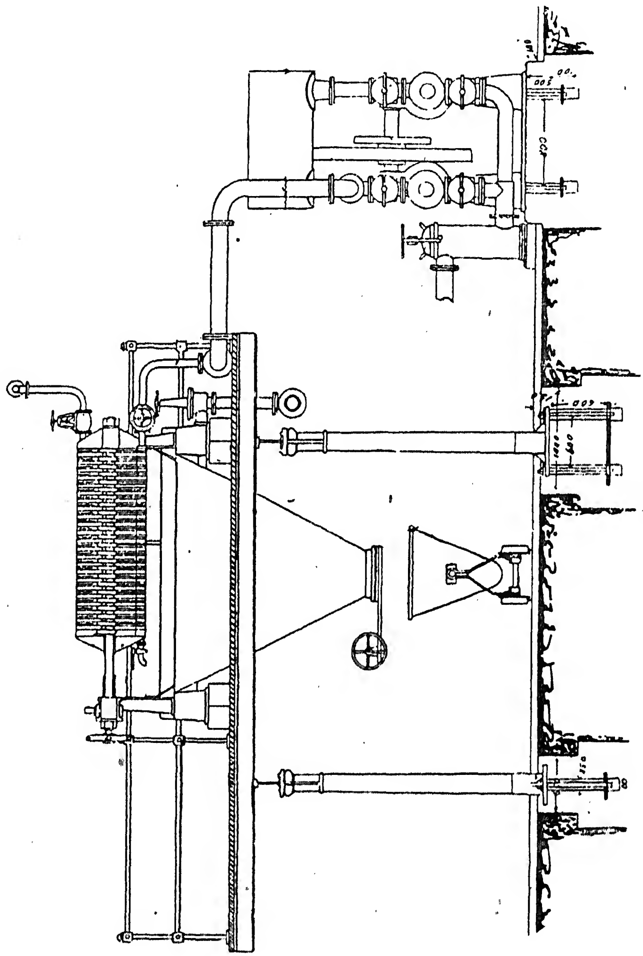


FIG. 98.—End view of general arrangement shown in Fig. 97.

Figs. 97 and 98 show the details and general arrangement of a complete installation of presses, including the pump and connections by means of which the juice is forced through the cloths under varying degrees of pressure.

In this case one pump, of sufficient power and capacity, serves to operate the entire range of five presses; but in

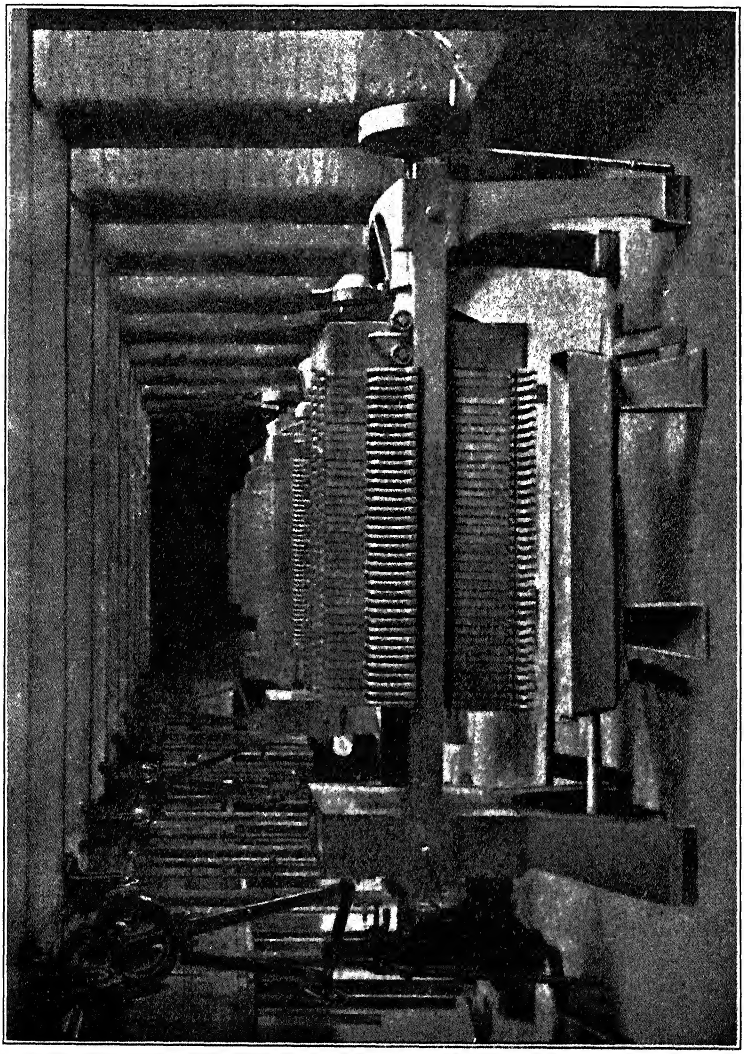


FIG. 99.—Range of filter presses in which each press is worked by its own adjustable pump.

special instances each press is furnished with its own pump. Fig. 99 supplies an interesting example of the latter arrange-

ment. Here a range of four presses is placed in a section of the sugar factory, from the ceiling girders of which a long line of shafting is suspended by hanger brackets. On the shafting, eccentrics are fixed opposite each press, which work the pumps attached to it. By means of an ingenious system of eccentric and suspension rods, the stroke of the pump can be regulated so as to force a greater or less quantity of stuff through any given press as may be desired at any given time.

Sometimes the use of a montejus is preferred to that of a pump. Then, it is customary to employ three such appliances to each range of presses. Thus, while one montejus is at work under steam pressure forcing the juice through the presses, another one is in course of filling, cleaning, and general preparation, so as to be ready for use when the first one is emptied. The third is used for washing, and is fitted with a steam coil for the purpose of heating the water used. Fig. 100 gives full particulars of such an alternative arrangement.

The residue from filter presses should appear in the form of an apparently dry cake. It should not contain more than 3 per cent. of crystallisable sugar, the proportion of the latter depending in great measure upon the degree to which the cake will admit of washing with water while in the press. Should the juice contain much gum, there is considerable difficulty in obtaining a suitable cake, with a consequent presence of too high a percentage of sugar. Juices rich in sugar are generally free from gums, and on this account a cake can often be got from them with a lower sugar content than when the juice has been of poor quality. With the ordinary filter press it is practically impossible to obtain a good cake unless a steady pressure of 40 lbs. on the square inch is maintained towards the end of the process. In some instances the cake, after removal

from the press, is mixed with water, boiled, and again filtered, but the expediency of this process depends entirely upon the market value of sugar at the time. Fig. 101 gives particulars of the press installation which would then be used.

The working of filters is one of the details of factory work which requires great attention. Insufficient sulphuring, improper tempering with lime, irregular steam or pump

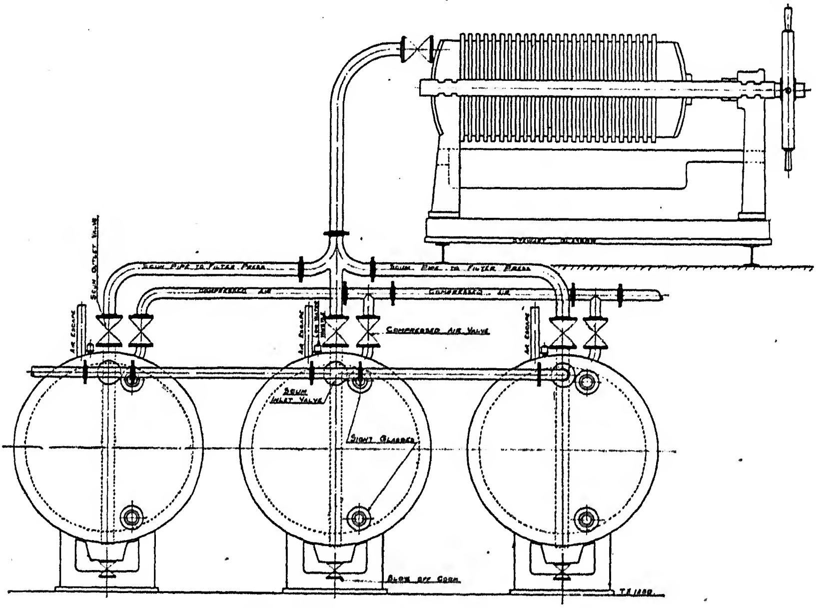


FIG. 100.—Filter press worked by montejus.

pressure, imperfect or otherwise unsuitable filter-cloths may occasion a considerable amount of loss. In a well-regulated factory the loss of sugar in this department should not exceed 1 per cent. of the sugar coming into the factory in the form of juice.

Various substances have been employed besides cloth as media for filtration. Megass has been used, but up to now filters with this filtering medium have not come into

general use on account of a tendency to induce a gummy condition of the juice, and owing to the trouble and cost of constant charging and dealing with the megass. This question, however, still attracts the attention of engineers and sugar technologists. Brown coal, a species of immature lignite, has also been used. When added in a finely divided form to the juice in the clarifiers, it subsides with the separated impurities, facilitating the subsequent filtration by maintaining the filter cake in an open condition. Direct decoloration of the juice is also claimed for it. Large quantities are required, however, to give definite results, and the consequent high cost has rendered the use of this body prohibitive. Another agent which has been tried to improve the filtering properties of the mud from the juice is impure kaolin or china clay, used in the same manner and for the same purpose as brown coal. The cost of the employment of this agent in the necessary bulk prevents the employment of it becoming general.

Sand as a filtering medium has been advocated from time to time, and although no filter of which it forms an integral part has come into general use in sugar-making, there seems to be great possibility of the ultimate application of sand to this purpose proving successful. The great difficulty to be contended with is cleaning the sand satisfactorily without removal from the filter; otherwise the cost of handling becomes excessive. This obstacle to general use has prevented the constant employment of the simpler and original forms of such filters, and in sugar factories in which they were actually installed their services have not been utilised any more frequently than could be avoided, the filters being chiefly held in reserve for emergencies. Experience has shown that in most cases the foul sand cannot be sufficiently cleansed by the washing action of an ordinary reversed current of water acting upon

it *in situ*. The filtering medium must be either completely removed from the filter or stirred up sufficiently in a suitable manner while within the latter, for the purpose of affording the water an effectual opportunity of ridding the sand of all sediment and sticky impurities.

Figs. 102 and 103 give particulars of a more advanced type of sand-filter, which has for its objects the amelioration of some of the accompanying troubles due to the necessity

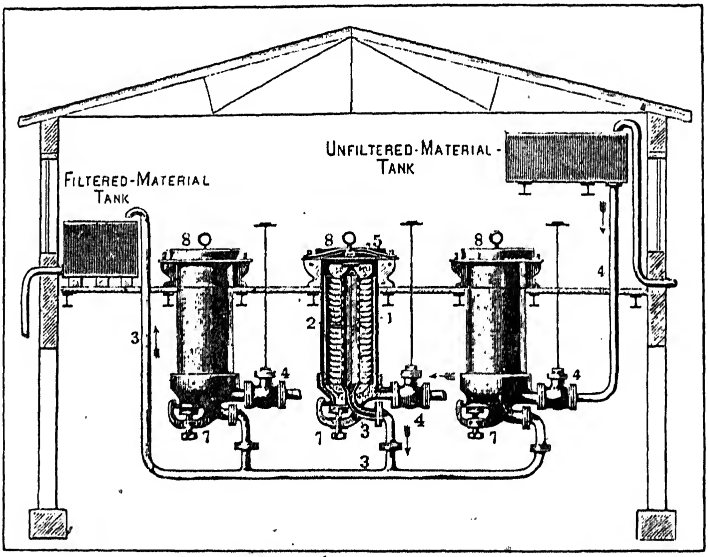


FIG. 102.—Battery of sand-filters for the filtration of cane juice.

of the frequent removal and washing of the filtering medium, and the attainment of the largest possible filtering surface within the most compact limits. Fig. 102 describes the general arrangement of a battery of such filters, and Fig. 103 is an enlarged section of each unit vessel. The latter is a suitably-sized cylinder, fitted in the centre with a perforated pipe, 2, of large diameter, both cylinder and internal pipe having conical terminations at their lowest extremities. Between the outside cylinder and the

perforated pipe 2 a system of conical rings, 1, is arranged. The largest and lowest of these rings rests on the cone-shaped bottom of the filter, and the upper and smaller rings sit in succession, the one upon the top of the other. Sand

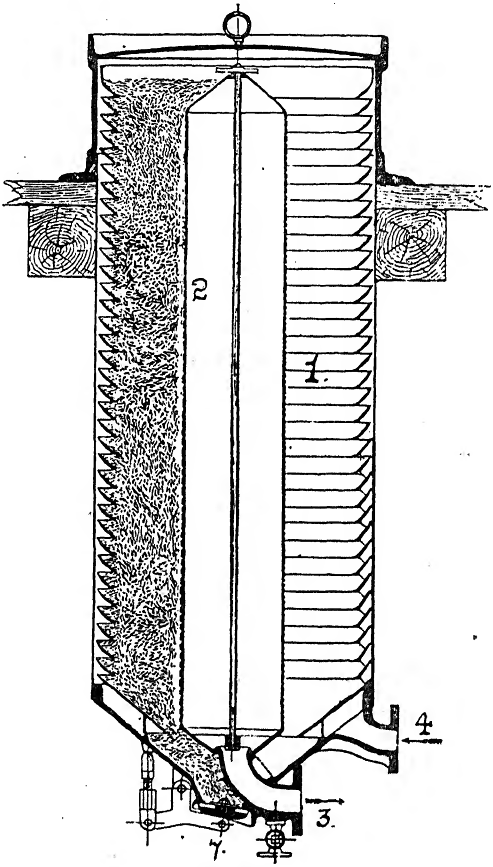


FIG. 103.—Enlarged section of one of the unit vessels forming a complete filtering battery, as shown in Fig. 102.

is filled into the space between the perforated pipe 2 and the saucer-shaped circumferences of the rings 1, and the juice to be filtered enters the filter through the inlet branch 4, thus filling the vacant space left in the external

cylinder, and, subsequently percolating through the sand, passes into the interior of the central perforated pipe, leaving the filter by the outlet branch shown at 3, having left the deposited solids distributed throughout the section of the sand.

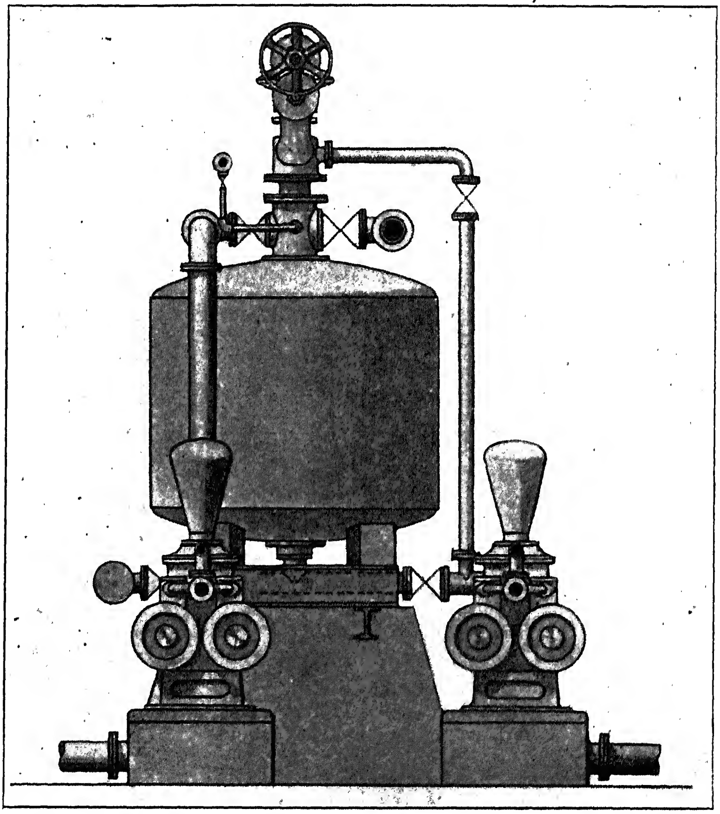


FIG. 104.—View of single vessel of sand-filter, showing pumps.

When the sand has become choked with impurities, the inlet-valve 4 can be closed, and compressed air can be admitted to the top of the interior of the cylinder to expel the remainder of the filtering juice which remains in the sand, and thus minimise loss of sugar. The compressed air

is then shut off, and the bottom outlet-door 7 thrown open. Water instead of juice is then admitted through the re-opened valve 4. This inrush of water passes direct to the outlet-door 7, washing away with it the whole of the scum-clogged and descending sand, which freely escapes into a suitable receptacle which is placed to receive it. The filter after washing is then empty and clean, and ready to be refilled with a fresh charge of sand, the previously used foul sand being taken away to be washed and made ready for use in one of the succeeding filters in the battery.

Figs. 104, 105, and 106 furnish details of a promising type of sand-filter, for all-juice use, which is intended to obviate the necessity for removing the sand from the interior of the filter when the former becomes foul and requires to be washed. Filters of this type consist of cylindrical mild steel vessels with dished tops and bottoms, having manhole doors in the top, and doors in the side for emptying the sand. In the bottom of each filter there is a central connection with hollow radiating arms carrying conical pots filled with coarse gravel and covered by finely perforated tops. The space from the dished bottom up to the lip of the conical pots is filled solid with concrete, so that there is no space for foul matter to accumulate. The space above the concrete, up to within a few inches of the top of the parallel portion of the body, is filled with suitable sand. Fixed to the top of each vessel there is a simple head box, through which passes a hollow spindle with a bevel wheel on the top, and hollow radiating arms at suitable heights, so as thoroughly to stir up the sand. Each arm is fitted with rakes and special spraying devices. The head box is fitted with facings and valves for the juice inlet and wash-water discharge, steaming-out connections, and a water connection leading to centre of hollow spindle. The bottom has a T-piece with valves and connections to the

clear-juice discharge on the one side and wash-water inlet on the other. Over the filters runs a countershaft with bevel wheels and clutch gear arranged so that any filter may have its stirring gear thrown into action. This countershaft is driven by a belt-drive from any convenient source of power. Duplex pumps for water and juice are provided.

The method of working is as follows: Juice from any desired source is discharged by the juice pump into the head box of the filter. Falling on to a splash-plate, it is distributed over the top of the sand, and by the pressure of the pump forced down through the sand, then through the conical boxes. Finally it is discharged by the outlet in the bottom to the main, and delivered to the evaporator supply tanks.

When the juice becomes so reduced in volume as to indicate that the filter has become dirty and requires cleaning, the valve between the juice supply and the filter is closed, also the outlet valve between the delivery at the bottom and the clear-juice main. Then the valve between the wash-out pipe and the bottom of the filter, and the valve between the head box and the wash-water discharge are opened, and the water pump started to deliver a large volume of water through the T-piece in the bottom of the sand-filter; this flows in a reverse direction to the juice, and gradually displaces all the juice which has been retained in the filter. This is returned to the scum blow-ups, and as soon as the falling density indicates that all the sweets have been removed in such manner and that only dirty water remains, the connection to the scum blow-ups is closed, and the connection to the drain is opened, a current of water being thus maintained through the sand and on to the drains. The valve from the wash-water pump to the vertical spindle is next opened, and the stirring gear clutch thrown in; this causes the hollow spindle with its arms to

revolve, and as they revolve the sand is stirred up, and further washed by means of the sprays proceeding from each hollow arm. As soon as the effluent water is perfectly clear, the wash-water pump is stopped, the water connections closed, and, if so desired, the plant thoroughly steamed out before the juice connections are re-opened.

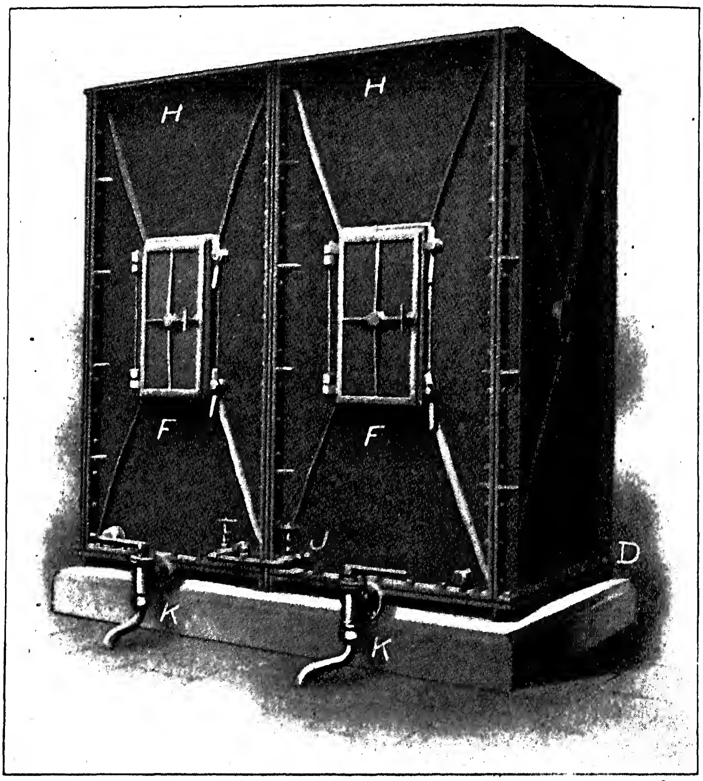


FIG. 107.—Exterior view of a double set of bag-filters.

It will be observed from the foregoing description that the sand should seldom be changed. If at any time its removal is necessary, for inspection of the interior of the filter, or for repairs or renewals, the sand-emptying doors provided on the sides of shells are used.

The whole of the clarified juice, or the syrup after concentration, is often filtered in bag or stocking filters. These, known as Taylor's filters, are shown in Figs. 107, 108, and 109, and consist of a group of from twenty-five to fifty strong bags or stockings made of stout woven filter-cloth. These are usually arranged in the manner shown in Fig. 109 at A, from which it will be seen that they are suspended in a manner suited to the continuous reception and inflow of the unfiltered juice. B is either a fixed or removable iron plate of considerable thickness, which is perforated with numerous holes, as seen in Fig. 108. These holes are fitted

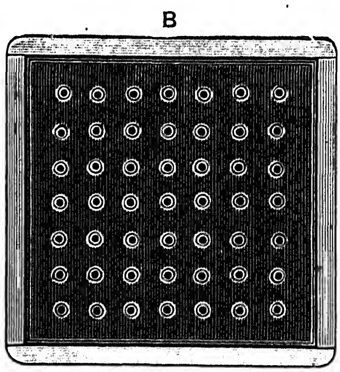


FIG. 108.—Plan view of the nozzle plate of a bag-filter.

with gun-metal sockets permanently fixed in the plate B, and furnished with screw threads for the reception of the gun-metal bell-mouthed cones, to each of which a bag is tied; or else are plain sockets, the bags being held in their place by means of a ring. The frame-plate B and its attached stockings C are enclosed in an iron box or casing, D, to which access is obtained by means of the closely fitting doors, F, seen in Fig. 107, an illustration which also gives a clear idea of the general appearance of a group of two or more such boxes or sets, as they would appear from the outside when at work. When the frame-plate and bags

are in their working position the sides of the chambers D extend a suitable height at H, above the level of the top of the frame-plate B, and into the upper tank thus formed the unfiltered juice is led by a pipe or gutter. It thus gravitates through the socket-holes and bell-mouthed cones into the bags, which in this manner are kept full under a trifling

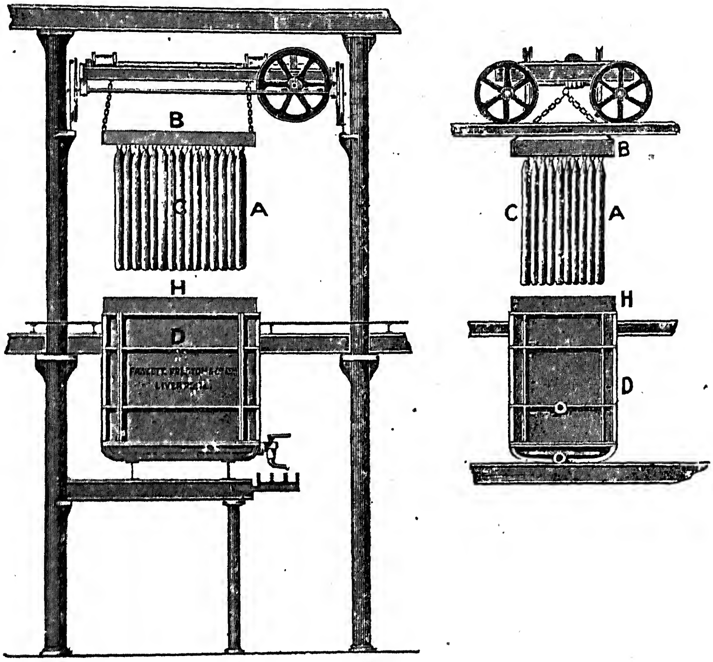


FIG. 109.—General view of a labour-saving arrangement which facilitates the removal and renewal of the bags.

pressure, and the juice percolating through the stockings is filtered, while the sediment is retained in these bags. In due course the latter become filled with fairly solid mud, and have to be removed from the chamber and replaced with a fresh set of clean stockings. This removal and replacement is frequently effected solely through the doors F, each bag being separately and successively taken out with its gun-

metal cone or ring to which it is attached. In order to save time, the more modern method displayed in Fig. 109 may very satisfactorily be adopted, more especially where a long row of filters is employed. In such case a frame full of clean bags is ready waiting to take the place of a similar frame full of dirty bags; and the latter can then be more conveniently removed, cleansed, and prepared to take the place of a succeeding batch of dirty bags. It is important that the juice to be so filtered should be as hot as possible, and a steam connection, J (Fig. 107), usually supplies steam to the interior of the filter chamber, so that the high temperature desirable for the promotion of rapid filtration may be maintained as much as possible. The filtered juice falls from the bags into the bottom of the chambers D, and is withdrawn thence through the outlet valves K on its way to the evaporators.

It will have been noticed during the perusal of the above description of the Taylor filter that the juice first enters the interior of the stockings, and, passing through the woven material of the latter, leaves all the sediment within them. At times it is somewhat tedious work to remove this fairly solid scum, and turn the long stockings inside out for the purpose of cleaning them thoroughly. An appreciation of the very considerable amount of labour thus involved has led to the adoption of another style of bag-filter, in which the unfiltered juice passes through the bag from the outside to the inside of same. Thus only the filtered juice obtains access to the interior of the cloth, and the sediment is left outside. These filters are also known as gravity-filters. Fig. 110 will assist in the explanation of their leading characteristics. Each unit consists of an oblong cast-iron rectangular box, A, of sufficient strength and long enough to contain about fifty brass spiral filter-bag frames, B. Over the latter suitable filter-cloth bags are drawn and

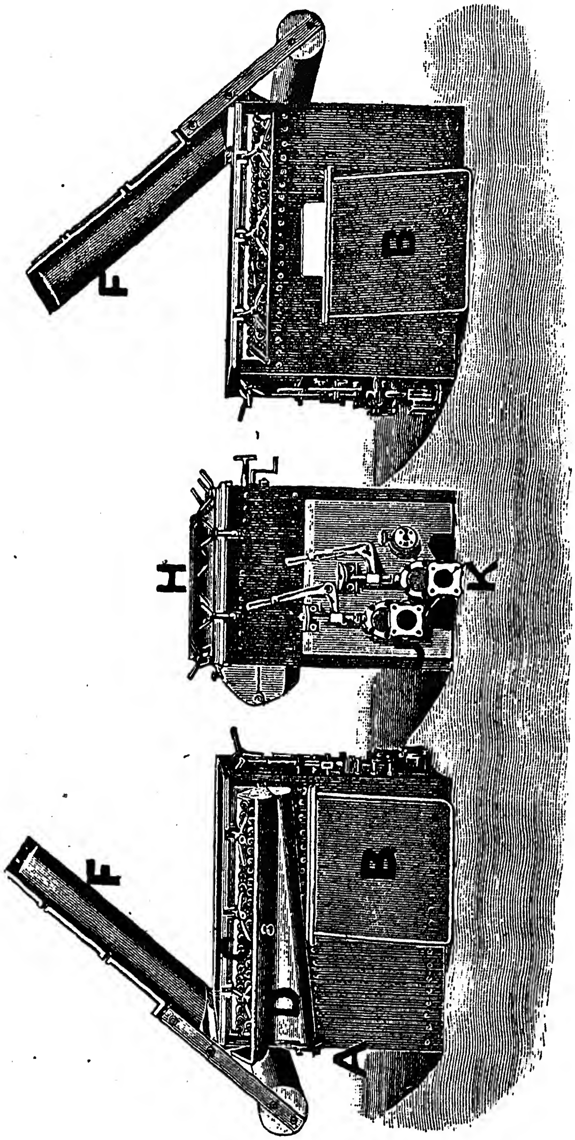


Fig. 110.—Gravity filters of the Danek-Phillippe type.

fixed, and the clothed frames are then placed in position side by side in the box A, as seen at C. It will be understood that if cane juice now fills A, it will entirely surround the

surfaces of each of the bags, and, passing through them, will leave the sediment behind in the box, or adhering to the exteriors of the bags. The frames and bags are so adjusted and secured that no juice can escape from the box, after once entering it, without passing through the bags, from the interior of which it is led by suitable ducts as filtered juice through D. Were the box A left open at the top, whilst at work, and the sides extended upwards to a moderate height so as to contain a small head of unfiltered liquor, these presses would, so far, at least, as their method of working is concerned, be the converse arrangement of the Taylor filters. They are, however, almost invariably fitted nowadays with easily removable covers, F, which can be firmly fixed and hydraulically sealed, as seen at H, and a moderate degree of static pressure is obtained in connection with the inflowing juice, by introducing the latter to the presses through a stand-pipe of sufficient height, which secures the assistance of moderate pressures to hasten the juice through the filter-cloths. The unfiltered juice enters the press chamber at J, and the sediment can be let out of the filter at suitable intervals through the outlet K, and it should be observed that, owing to the fact that the clothed frames are constantly standing immersed in the hot liquor, much of the mud, which would otherwise adhere to the external surfaces of the bags, is being continuously washed off them, falling to the bottom of the chamber A. By this action the presses remain at work for longer periods of time, without cleaning, than would otherwise be the case.

Filtration of "bottoms" and scums is not invariably carried out, other conditions than those of mere sugar-making influencing their manner of treatment. It may be that sugar-making, although of great importance, is not the primary economic feature of a sugar-cane estate. In Jamaica, and other places where rum is a speciality, the

profit of a sugar estâte may depend upon the value of the rum crop, the flavour and consequent high price of the latter resulting in great measure from the free use of clarifier-bottoms and "skimmings." This practice leads to a sugar better in quality, although less in quantity, and a better rum of greater quantity than would accrue through the employment of the ordinary procedure. The limited character of the high-class rum market does not, however, encourage the maintenance of this principle.

CHAPTER VII

CONCENTRATION OF THE JUICE

THE impurities of the juice have now as far as possible been eliminated, though there still remains the saline matter originally present, together with some of the lime added in clarification. Phosphoric and sulphurous acid are also found in some quantity—the former in the form of phosphates and the latter of sulphites, if yellow or white sugar is made; while some of the gums, if originally present, with traces of colouring and albuminous matter, remain behind in solution. In the case of the carbonatation process, there has been a disappearance of uncrystallisable sugar. A small proportion of the crystallisable sugar (about 1 per cent.) also remains in the filter cake. When no water has been added for purposes of maceration, the density will be somewhat higher than that of the original juice, owing to evaporation during the process of heating. Although there has been a loss of bodies heavier than water in clarification, which would tend to lower the density of the juice, this has been more than compensated for by the loss of water in such incidental evaporation, especially where eliminators have been used. The various chemicals added and remaining in solution also tend in the direction of rise of density. When maceration has been employed, the density of the juice depends largely upon the proportion of water added at the mills. The juice at this stage should present a clear and bright yellowish to olive green colour, according to the class of sugar being made, a slight opalescence appearing in the

case of the manufacture of Demerara crystals, as the result of the "tempering" employed. The next step in the process of sugar-making is that of concentration, with the view of preparing a syrup suitable for the subsequent crystallisation process. This means, in modern sugar-making, that, with normal juice, say possessing a density of 10° Bé., about 75 per cent. of the original volume, together with the water due to maceration, has to be removed.

In the early days of sugar-making, the boiling was done entirely in vessels exposed to the atmosphere and heated by fires kindled with wood, or by the megass or bagasse—the crushed cane residue from the mills, dried in the sun to render it suitable for ready burning. Indeed, where the primeval tropical husbandman grew and ground his few canes, the pot in which the clarification was conducted supplied also the evaporating vessel. When, however, operations were conducted on a larger scale, instead of a single pot, a series of caldrons or coppers were employed, built together with brickwork, and so arranged that the surplus heat of the fire under the first copper, or tayche, was utilised to heat the succeeding vessels; a chimney at the end of the battery opposite to the furnace carrying away the waste products of combustion, and providing the necessary draught. These batteries consisted of four or five vessels, the first being used also for clarification purposes. A previous illustration (Fig. 72) taken from the work of Père Labat on the West Indies, published in 1722, gives an excellent idea of the "copper wall," as then used in Guadeloupe and Martinique. It differs but little from that in use in the present day, but from the author's description of the sugar-making process then extant, the third "tayche" was also used for clarification, the extract of herbs then used being, as already observed, added at that stage of the process. Fig. 111 gives a plan and a longi-

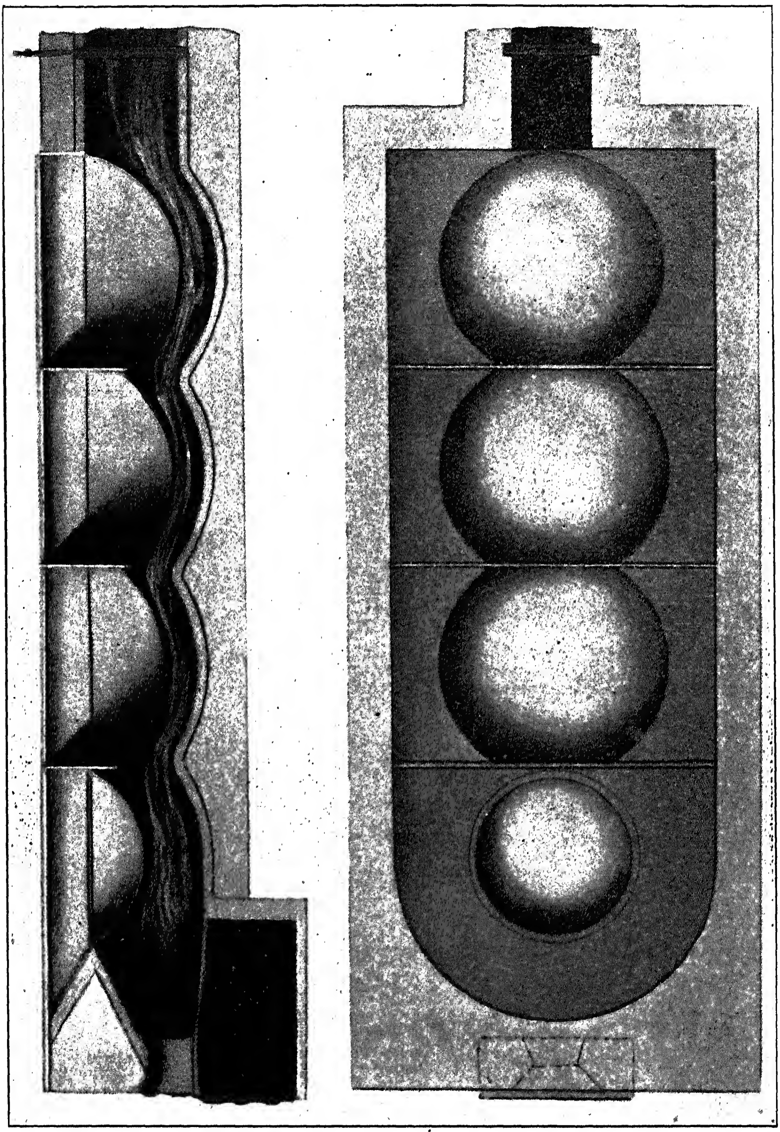


Fig. 111.—Plan and longitudinal section of a modern "copper wall."

tudinal sectional elevation of a modern copper wall which contains four of these tayches. It will be noticed that the latter are nowadays of considerable size, the total juice contents of such a battery frequently amounting to some 3000 gallons, to enable the battery to cope with the larger quantities of cane juice which have usually to be dealt with in a modern sugar factory.

The position of the fire-grate, and the action of the flames upon the contained fluids, will be appreciated by an examination of the illustration; and it should be noted that the inflowing juice is first directed into the largest tayche or "grand copper," which is situated farthest away from the fire. As the juice is being skimmed and boiled, it is also baled from tayche to tayche, as already described, until it reaches the smallest copper fixed almost immediately above the fire-grate, from which, in some factories, it is usually withdrawn to proceed to the vacuum pans. Various degrees of concentration of the juice are attained by this apparatus, the results depending upon the class of sugar which is being made. When a high class of vacuum-pan sugar has to be produced, the juice will frequently be removed from the copper wall at a density of some 17° Bé., while in cases of the production of muscovado sugar the higher density of 48° Bé. is attained. In the great majority of sugar factories the waste heat from these batteries is utilised to raise steam for factory purposes, and in numerous cases the entire steam requirements are thus met. Fig. 112 shows how a steam-boiler is usually added and embodied as an almost indispensable accessory to the complete setting of most copper walls.

These batteries, in the case of the manufacture of lower-class sugars, did the whole of the work of concentration up to the crystallising point, and do so still in the few cases where muscovado sugar is made. The great objection to

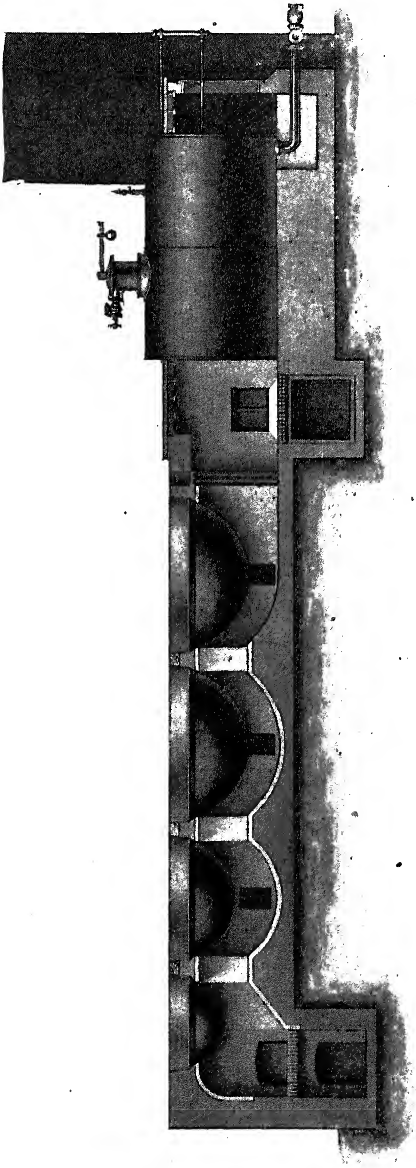


FIG. 112.—Sectional elevation of setting of a copper wall, with attached steam boiler.

them lies in the injury done to the juice by the prolonged exposure to high temperature while in contact with air. As juice becomes concentrated the boiling-point rises, and as the boiling-point rises the loss from what is known as "inversion," the formation of uncrystallisable sugar from the crystallisable, occurs. This action takes place with special force in the presence of acids. The juice boils tumultuously in the majority of the tayches, and as it is baled by the lusty negro from copper to copper, contact with air at the high temperature produces or intensifies acidity, the loss of sugar from this cause being thus accentuated. As mentioned under the head of Clarification, the effect of the usual tempering of juice is to produce a faintly acid or neutral reaction. This soon develops, in circumstances such as these, into pronounced acidity. Exposure to air of clarified juice also has a darkening effect, due to the result of oxidation.

Various modifications of this type of copper wall are more or less in use in various countries, and Fig. 113 shows an arrangement which is commonly known as the "Jamaica Train." It is composed of a suitable number of either cast or wrought iron or steel hemispherical pans, preceded by a shallow oblong pan which is mounted at a higher level than the circular pans, and in such a manner that it may act, if so desired, as a defecator. The latter is provided with a discharge pipe and cock, through which the defecated juice is withdrawn into the circular evaporating pans as required. To avoid loss of juice by its absorption in the surrounding brickwork, and generally to ensure maximum cleanliness, the evaporating pans have a capacious skimming-tray secured to their upper edges, which is provided with a suitably raised outer rim. It will easily be seen that the methods of manipulating this apparatus are practically identical with those employed in the case of a copper

wall, with the direct heat of a fire as the evaporating agent.

Fig. 114 shows a second modification of the copper wall,

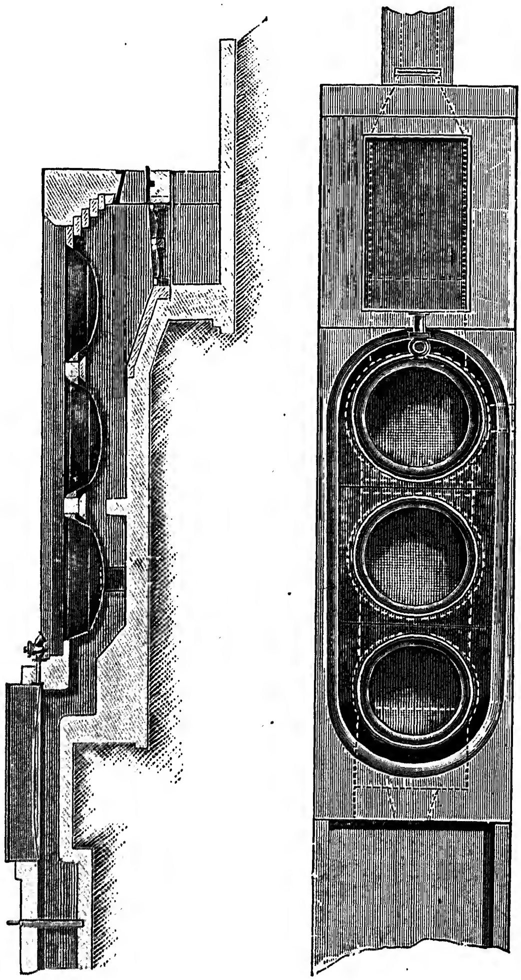


FIG. 113.—Plan and longitudinal section of a Jamaica train.

which takes the form of a terrace battery of open under-fired evaporating pans used in conjunction with a final "tilting" pan. This style of juice-boiler is much used in

certain localities, and presents decided labour-saving advantages. As will be seen from the illustration, it con-

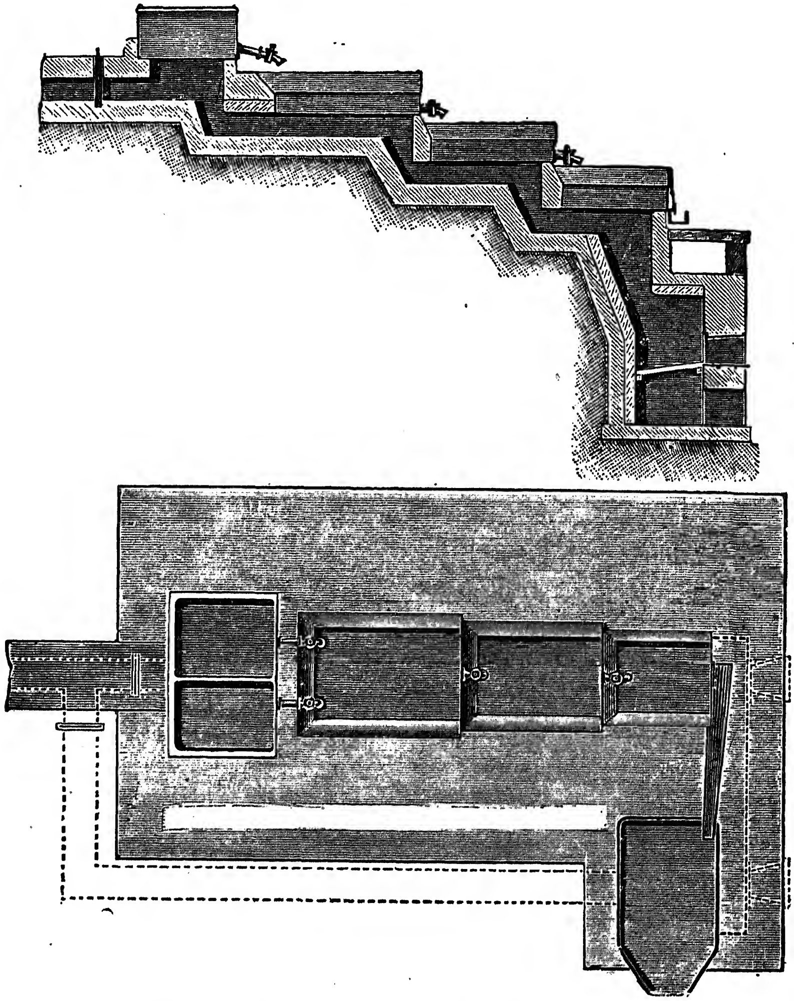


FIG. 114.—Plan and longitudinal section of a terrace battery of open under-fired evaporating pans.

sists of a series of specially shaped rectangular pans, of moderate depth, placed in terraces, the one above the other.

These pans vary in size, and are so arranged that the more concentrated the juice, the smaller the pan, and the more intense the heat which is applied to it. The uppermost pan first receives the incoming juice, being divided into two compartments, which may each be used alternately for the purpose of defecating and preparing the juice for concentration. The flue at this point is likewise divided with the same object in view, and fitted with controlling dampers. The defecated juice is now drawn, as required, from one of the divisions of this upper pan into the first and adjoining evaporating pan, the rate of flow being controlled by a suitable adjustment of the cocks provided for this purpose. In the same way, the partially concentrated juice is next drawn from the first to the second, and then from the second to the third or syrup pan, the flow of juice from pan to pan being regulated as before by the cocks attached to each vessel. A certain degree of concentration having been attained, the syrup is then withdrawn from the syrup pan into a gutter, shown in the plan, which leads it into the finishing pan, which is set to one side of the main battery. This finishing pan, which is provided with its own separate furnace, sits upon specially arranged brickwork, so that it can be tilted for the emptying out of its contents, and it is within this vessel that the highly concentrated juice is boiled to "string" or crystallising point. When this stage is reached, the pan is tilted through the agency of suitable gear, and its contents are discharged into coolers for further treatment in moulds or centrifugals.

A third system of concentration by direct fire-heat is shown in Fig. 115. In this case the train or battery consists of a very long and shallow pan of suitable width, which is divided transversely by numerous plate divisions. These divisions, consecutively, have openings at alternatively opposite sides of the train, thus forming a long and

tortuous channel extending from end to end of the battery, down which the juice meanders continuously from side to

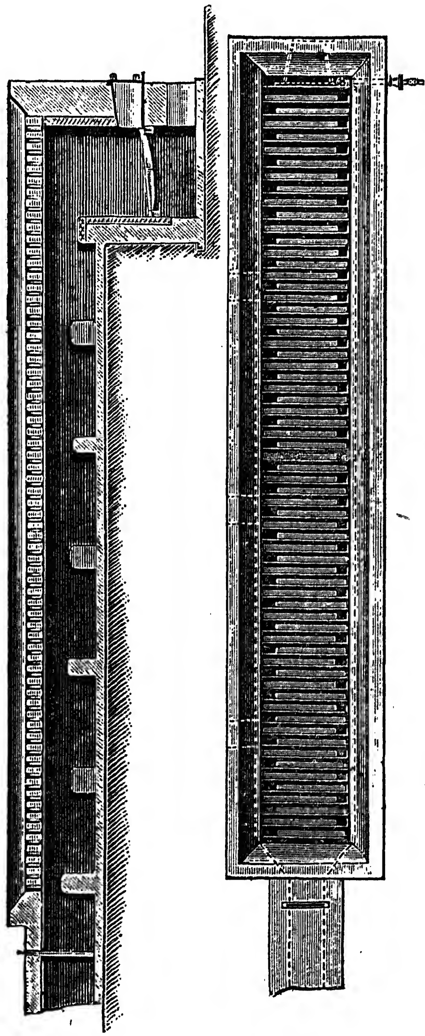


Fig. 115.—Plan and longitudinal section of a Panela train.

side, between the divisions, until in course of time it arrives at the outlet situated near the firing end of the battery, which it first entered at the end farthest from the fire.

The admission and subsequent discharge of the juice are so regulated, that by the time the latter has reached the point of withdrawal, it has been concentrated to "string" point, and is ready to be put into coolers or moulds. In the case of this apparatus the discharge of the dense syrup is effected by means of a specially arranged syphon.

Still another form of copper wall has been very extensively employed, in the form of what is known as a "concretor" plant. In this apparatus the bulk of the evaporation is effected in a series of iron trays fitted with specially arranged partitions and shallow channels, which, as in the case of Fig. 115, cause the juice, in passing from top to bottom of this inclined battery, to travel a comparatively long distance. These trays, with one important exception, are heated in the same manner as the copper wall and its relative apparatus, and, as the juice flows in a thin layer, evaporation proceeds with considerable rapidity. It should, however, be noted that in the case of this concretor the thin juice is first subjected to the greatest heat, and travels, with regard to the position of the fire, in a direction opposite to that pursued in the case of each of the foregoing evaporators. Fig. 116 gives general details of the arrangement of this apparatus. The main portion A, comprising the trays, may extend over a length of some forty feet, and forms a gentle zigzag incline, down which the juice slowly runs. At the foot of this incline an air-heater, D, is placed, the heated air from which is caused, through the action of a fan, to pass through the revolving cylinder E, where it meets with thin films of partially concentrated juice which have been led into E from the trays, thus completing the concentration. The interior of E is fitted with a number of scroll-shaped plates, by means of which, in combination with the rotation of the cylinder, large surfaces of the syrup are exposed to evaporation under the action of the current of

heated air which is blown through it. After some twenty minutes' treatment in E, the concentrated juice is cooled to

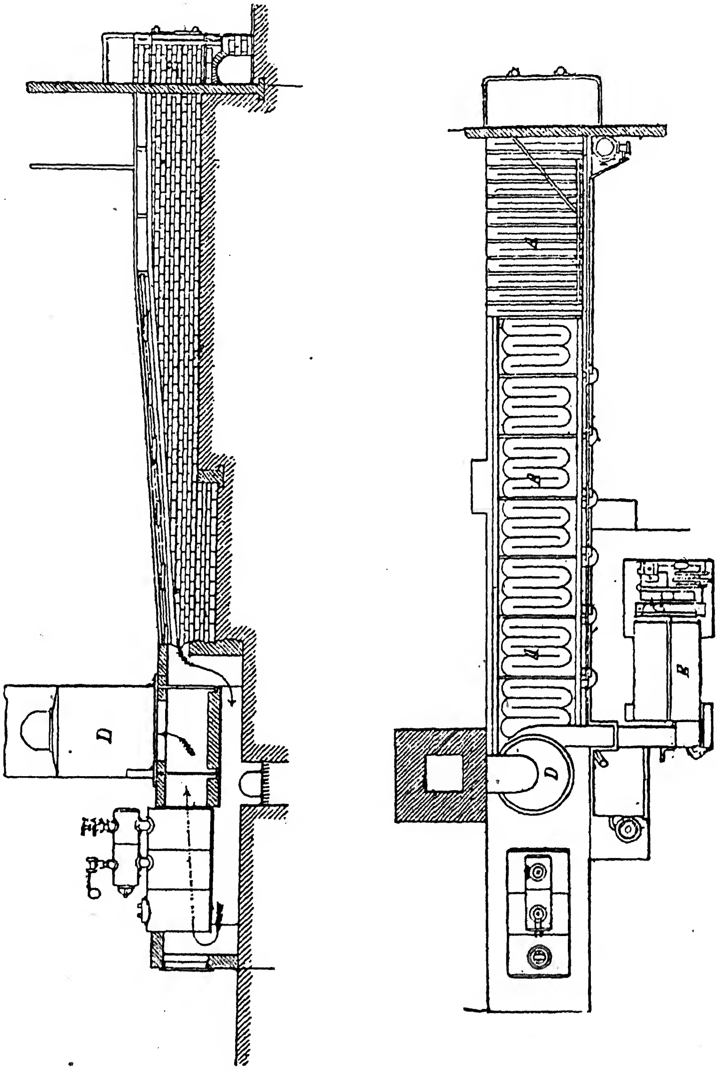


FIG. 116.—Plan and longitudinal section of a concretor with attached steam-boiler.

a solid mass, in small moulds, for shipment to the refineries, where it undergoes further treatment. In some localities

the tray portion, A, of this concretor has been used without the accessories D and E, and in this curtailed form it has taken the place and performed the duties of evaporation which would have otherwise been effected by one or other of the three preceding " walls."

In each of the foregoing systems of evaporation, the application of the direct heat of a wood or megass fire has been relied upon as the agent wherewith to effect the concentration of the cane juice. In some cases such methods are liable to be wasteful of fuel. In others the amount of hand labour involved is a serious obstacle to economy; and in all of them the application of so intense and dry a heat as that of a megass or wood furnace is open to serious objection. The temperature in furnaces of this class may range to fully as high as 2,500° Fahr., and the corresponding temperature prevailing in the striking tayche of a copper wall is at any point of the boiling mass not less than from 230° Fahr. to 235° Fahr., while it must necessarily be greater in the bottom of this pan, which lies almost immediately above the fire-grate. The most wasteful form of these directly heated evaporators, both as regards fuel and labour, is that shown in Fig. 111. But while the labour bill remains unaffected, economy of fuel is promoted by the installation of a steam-boiler at the end of the " wall " in order to effect the utilisation of the waste gases for steam-raising purposes. Similarly, Fig. 114 indicates an effort to abolish the employment of the gang of labourers who would otherwise be required to remove the juice from pan to pan. The Panela train (Fig. 115) and the concretor (Fig. 116) have the same object in view; the latter also reversing the application of the direct heat, and applying the fiercest temperature to the thinnest juice—as already mentioned. Taking the various drawbacks of the earlier and cruder processes into consideration, it is not surprising

to find that steam heating has come universally into vogue in all modern factories of the best class, although its adoption has been marked by a gradual development and elaboration,

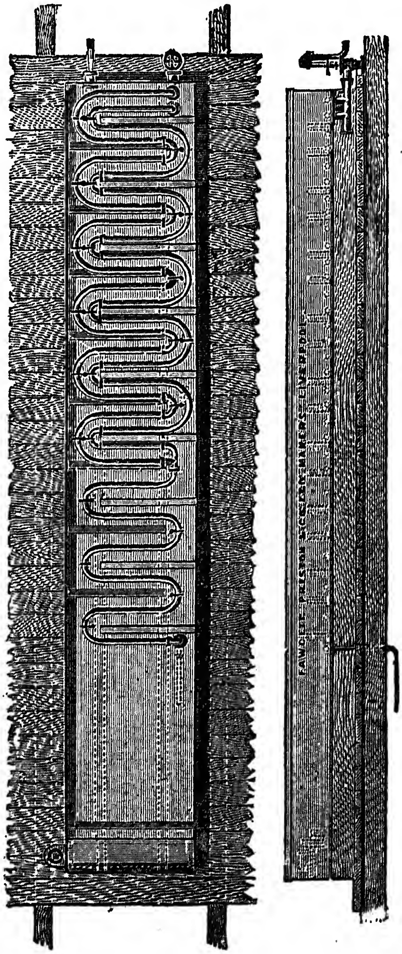


FIG. 117.—Plan and elevation of continuous open cleaning and evaporating steam train.

with a view to concentrate the cane juice through the agency of the lowest possible temperatures.

The simpler forms of steam evaporating pans retained, to some extent, the general style of form and arrangement

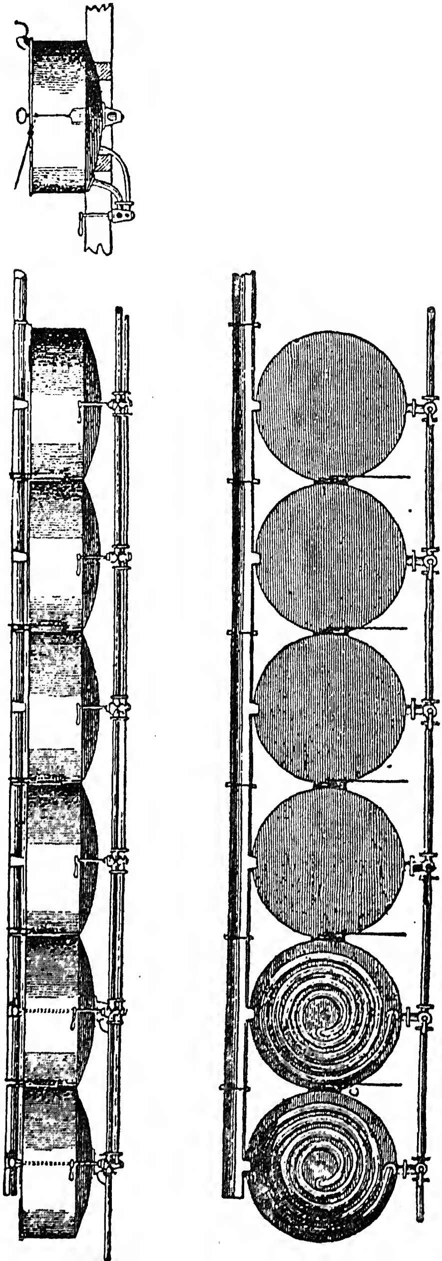


FIG. 118.—Plan and elevation of open cleaning and evaporating steam battery composed of a series of circular pans.

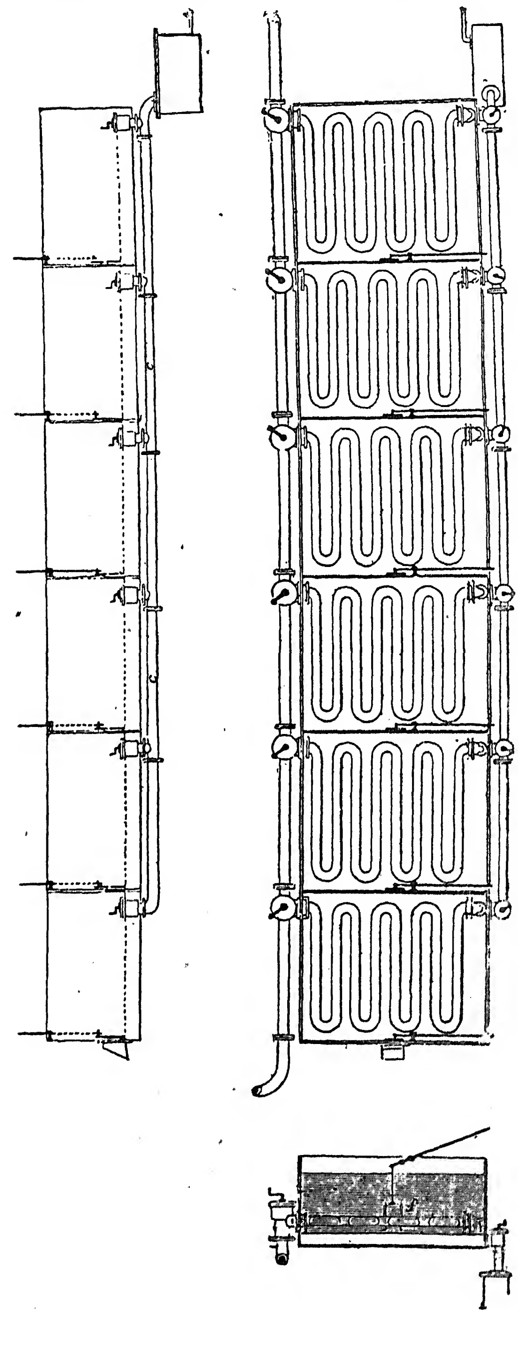


FIG. 119.—Plan and elevation of open cleaning and evaporating steam battery composed of a series of rectangular pans.

which characterised the older direct-fired evaporators, as will be seen in Fig. 117. In this case, as in Figs. 115 and 116, the juice to be concentrated runs slowly from end to end of a tortuous channel or gutter, in which steam-heating coils are located, the latter taking the place of and performing the act of concentration which would formerly have been effected by a fire acting beneath these trays. Or, as in Fig. 118 (like the old copper wall), the juice was passed on by means of suitably arranged valves from unit to unit of a

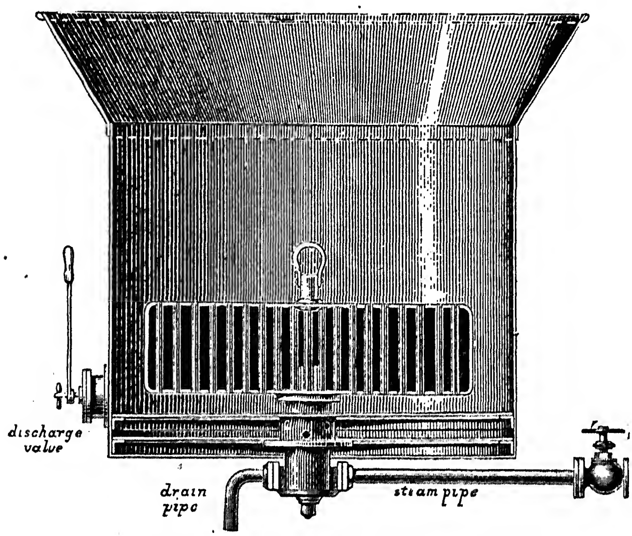


FIG. 120.—Aspinall evaporating pan.

series of circular pans fitted with steam-heating coils. The next illustration, Fig. 119, shows a very similar steam battery, in which the tanks or pans are of a rectangular shape, the arrangements of the steam pipes being modified accordingly. Each of these trains can be worked on the continuous system when desired; but some sugar-makers prefer to deal intermittently with separate batches of juice at a time, or, at all events, complete the concentration "to grain" in a separate apparatus. In either of such cases an

Aspinall, Brocklehurst, or Simpson pan is frequently used, and Figs. 120, 121, and 121A give full particulars of such evaporators. The pans themselves are constructed of steel

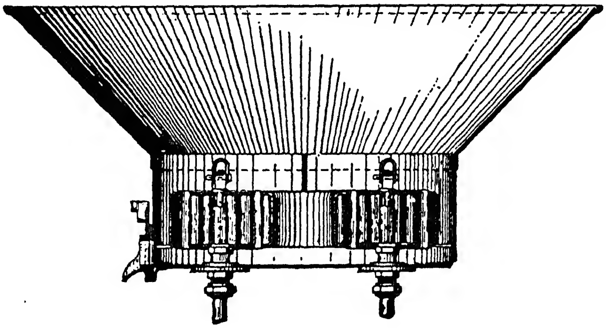


Fig. 121.—Simpson evaporating pan.

plates, within which removable or fixed calandrias are provided, fitted with numerous brass tubes, which permit of an efficient circulation of the juice. High-pressure steam is admitted to the drums or calandrias, and the thin juice

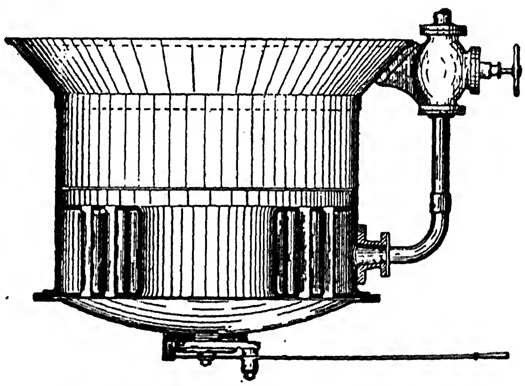


Fig. 121A.—Brocklehurst evaporating pan.

concentrated to "striking point." It will also be noticed that these pans are provided with large-sized striking-doors, which permit of the rapid discharge of the highly concentrated contents.

Three of the above evaporators (Figs. 115, 116, and 117) may practically be termed film-evaporators; at all events they indicate an approaching appreciation of film-evaporation. It is well known in practical work that, other things being equal, this system of concentration is, for obvious reasons, more efficient in certain respects than treatment in bulk; and Fig. 122 shows how it has been partially applied to other forms of evaporators. A is a semi-cylindrical and open vessel or trough which contains the juice to be concentrated. B is a reel, composed of two

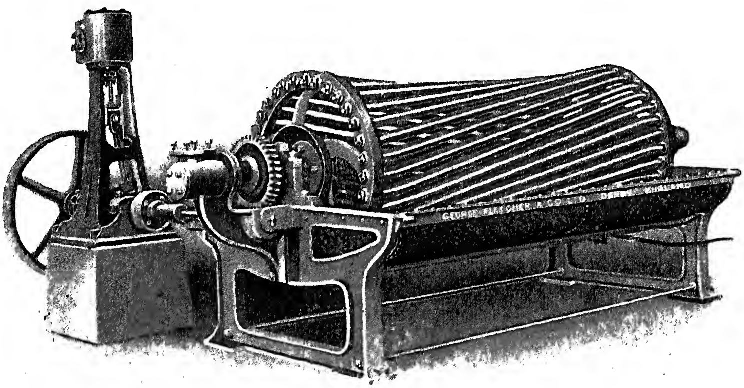


FIG. 123.—Wetzel evaporating pan with inclined heating tubes.

hollow end discs connected together by solid drawn brass tubes of considerable length, and this slowly revolves in the trough, the reel being rotated by the engine and gearing attached to one of the end frames of the machine. High-pressure steam is admitted to the discs and the tubes at one end of the reel, and the condensed steam, or hot water, is withdrawn through a steam trap at the other end. The reel thus constitutes the heating surface of the apparatus. It will be readily understood that as the latter revolves the discs and tubes carry on their surfaces thin films of

juice, the water from which is thus quickly evaporated under the heating influence of the steam contained within the reel. Sometimes the trough A is steam-jacketed; and,

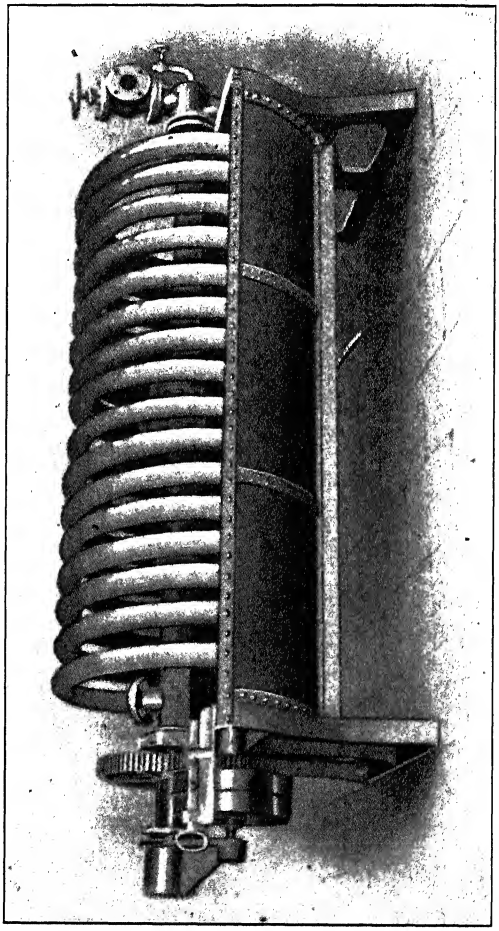


FIG. 124.—Wetzel evaporating pan with helical steam heating surface.

in the earlier machines of this type, this jacket was the only point at which steam was applied. In this form of evaporator the reel was simply constructed of solid sheet discs connected by metallic rods, which were not intended to do

more than expose the hot juice to the atmosphere, and thus facilitate the escape of the contained vapour. In the use of these initial forms of Gadsden and Wetzel pans, it was found necessary to limit the speed at which the reel revolved, lest objectionable splashing and churning of the liquor should take place, and to ameliorate these drawbacks the tubes of the heating surface were bent somewhat helically, as seen in Fig. 123. A still further step in this same direction will be noted in Fig. 124, in which the revolving heating surface assumes a greatly modified form. Here the axle of the reel consists of a strong steam pipe with suitable branches, to which is attached a long spiral coil of large-bore copper piping which constitutes the heating surface, and dips in and out of the liquor in the trough without undue splashing and agitation of the contents of the latter. A further advantage is shown to a more marked

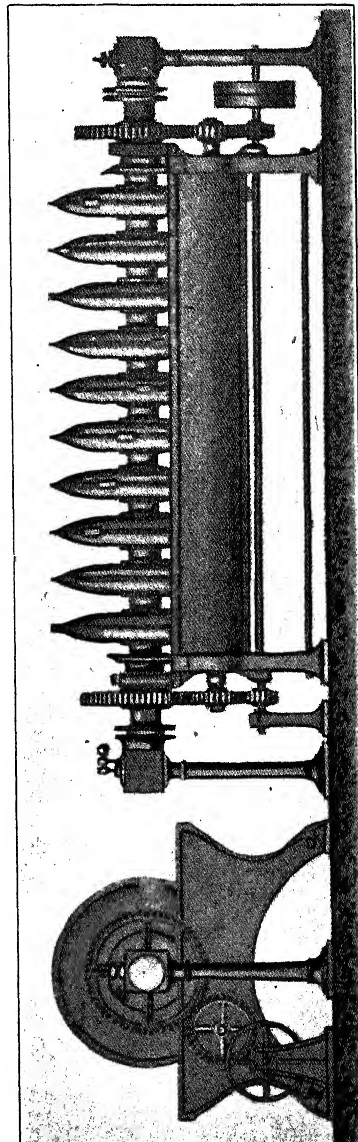


FIG. 125.—Longitudinal and end elevations of Bour evaporating pan.

degree by Fig. 125, which defines the Bour pan. It had been noticed, in the use of the earlier forms of this class of evaporator, that larger grains of sugar were produced on the vertical surfaces of the heating surface than on the horizontal portions, more especially on the discs, and the Bour pan was the outcome. In this machine hollow steam drums or discs, mounted on a hollow iron steam shaft, supersede the piping and permit the revolutions of the reel to be doubled, with an approximately corresponding increase in the amount of the work performed. As in the similar apparatus of this type, ingenious arrangements are arranged inside the discs which withdraw the water of condensation from them, and thus prevent water-logging.

In the use of many of the evaporators described above, there was considerable danger of injuring and even caramelising the juice, and this was more especially the case when thin films of juice were subjected to dry fire-heat. Moreover, long exposure to the atmosphere appears to be equally as mischievous as the effect of high temperatures, and it is difficult to avoid one of these two dangers without an increased risk of incurring the other. It will thus be recognised that the great difficulty, as well as the main object in view, is to avoid both dangers. Again, there is a well-known difficulty in the boiling of dense liquids, which consists chiefly in the lessened ability of the vaporised water to force its way through the superincumbent mass of dense juice, and ultimately to escape against the pressure of the atmosphere. A prolonged experience of these difficulties ultimately led to the adoption of boiling *in vacuo*.

The introduction of the vacuum pan (Fig. 126), in which the boiling temperature is lowered by the creation of a vacuum, and where there is practically no contact with air, was the first step towards remedying the evil resulting from open evaporation. Its advent restricted the duty of

copper wall as an evaporator. In fact, the latter acted e as an eliminator and less as a copper wall, according ne power of the vacuum pan plant attached to it. As, ever, concentration in a vacuum pan is a costly opera- as regards fuel, the use of a copper wall was still con- ed to effect a large proportion of the evaporation.

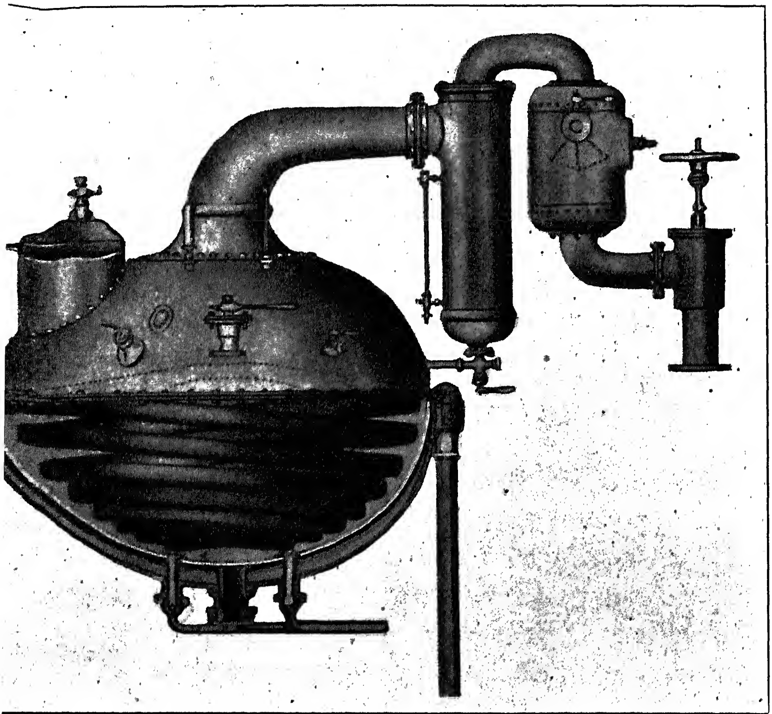


FIG. 126.—Early form of vacuum pan.

tiple crushing also, in which the juice is far more rged with impurities than when the old-fashioned m or wind mill was used, and where damage to the e from open boiling is far greater, tended further to do y with open evaporation, and the vacuum pan became re and more of a necessity. Following the intro- tion of the vacuum pan, and later as an indispensable

adjunct to multiple crushing, the multiple system of evaporation, taking the place of the evaporation hitherto done on the copper wall, came into general use.

In the copper wall itself, the only attempt at economy of heat lay in the utilisation of the waste heat from the first copper (under which a fierce fire was necessary in order to deal effectually with the already dense syrup) to heat the juice in the second, the effluent heat from the second heating the third, and so on, the heat value of the vapour from each copper being still lost in the atmosphere. Early in the last century, however, experiments were made on the Continent in connection with the then rising beet industry in the direction of the utilisation of the vapour heat from one vessel to effect evaporation in a second, and so on. Three vessels were more generally used; of these the first two were closed, except for a pipe which conducted the vapour arising from the ebullition of the one to the heating space of the next, steam being applied in the heating space of the first vessel. As the heating medium in each instance must be hotter than the body to be heated, and as the boiling-point of the last or open vessel was that of the atmosphere, it followed that the boiling temperature of the first vessel, and consequently of the initial steam, had to be considerable for substantial work to be done. The juice, therefore, had by this system the great disadvantage of being subjected to an extremely high temperature. These disabilities were more than sufficient to counterbalance economy of fuel from the threefold work done by the steam.

The vacuum pan, which was invented by Howard about 1812, removed this disability; and in 1845, Rillieux, a French engineer residing in the United States, took out a patent in that country for a multiple evaporator, in which, by the use of a vacuum pump, and by condensing the

vapour with water, as in the vacuum pan, a suitable boiling temperature was obtained in the last vessel, and *pro rata* in the others, which at once brought the system within the range of practical sugar-making. All modern multiple evaporators are based on Rillieux's system, save in the detail that a granulating pan, rarely seen in cane-sugar factories, worked by the vapour from the first vessel, was included in the original scheme.

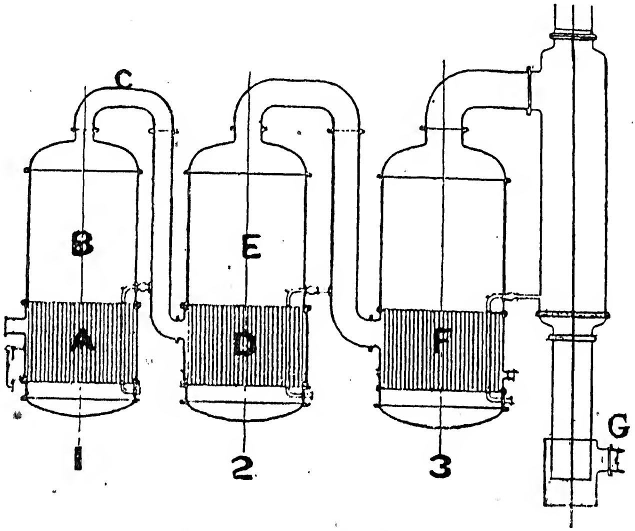


FIG. 127.—Section of a triple effect.

Fig. 127 shows the principle upon which multiple evaporators are constructed. Into the steam space A of the vessel 1, steam is admitted, which boils the contents of this vessel in the space B. The vapour from vessel 1 passes through the connection C into the steam space D of vessel 2, and boils the liquor in the space E of that vessel, the vapour from which passes in turn into the steam space F of vessel 3, the vapours from the juice space of this last vessel passing to the condenser G. Here it meets with a jet of water drawn in by the vacuum, and is condensed, the condensed

vapour being taken away by the vacuum pump. It is thus seen that the initial steam brings about the boiling in all the vessels, and may thus be looked upon as being used as many times over as there are vessels in the apparatus. This result, brought about by the lowering of the boiling temperature in the last vessel by means of the vacuum pump, produces a lower boiling temperature in any one vessel than in the one immediately before it. In this way the heat of the initial steam is limited to a moderate degree of temperature, and is again used in each vessel, the cost of this economy being that of the fuel required to work the pump which maintains the vacuum in the last vessel, which in many cases also removes the water from the condenser. The juice is made to travel slowly from one vessel to the next through suitable connections which are fixed between the respective vessels, the difference in the vacuum existing in the adjacent bodies being sufficient to effect this, while the concentrated juice from the third vessel is drawn off by a pump.

By reason of the greater amount of heat required to evaporate a given weight of water as the boiling-point is lowered, and also from losses from radiation unavoidable in practice, a given weight of steam introduced into the first vessel will not evaporate n times its weight, when n vessels are used. In practice, however, the following figures, representing the amount of evaporation resulting from the use of 1 lb. weight of steam in the first vessel, are obtained. It should be pointed out, however, that the whole of the evaporation in these results is credited to the steam used, whereas a small portion of it is due to the heat of the hot juice going into the first vessel. As the latter enters at a temperature of, say, 190° Fahr., and leaves it at, say, 130° Fahr. in greatly reduced bulk, a certain amount of heat has been given up in transit through the

evaporator which has produced a definite amount of evaporation:—

Double effect	1·8 lbs.
Triple effect	2·7 ,,
Quadruple effect	3·5 ,,
Quintuple effect	4·3 ,,

As already mentioned, in calculating the net economy, purely from the point of view of fuel, as compared with atmospheric evaporation, the proportion of steam expended in running the vacuum and other pumps connected with the apparatus should be deducted.

It is now desirable to describe more fully the structure and work of an ordinary standard multiple effect. In this connection it should still be borne in mind that the vacuum pan was the earliest form of apparatus in which evaporation was performed in vacuum (Fig. 126). This evaporator, however, was chiefly arranged for a double purpose. It had not merely to complete the concentration of the cane juice for the purpose of producing lower classes of sugar as with the older evaporators, but it was also intended to ensure the formation of a suitable mass of crystals which would constitute the higher classes of sugars that are nowadays placed upon the market. The characteristic shape of a vacuum pan, and the arrangement of its heating surface, were therefore moulded in accordance with such special requirements, as shown in this illustration, which, notwithstanding numerous modifications, is nevertheless the approximate basis of all modern vacuum pans. It is not necessarily constructed on the lines best suited to the requirements of economical evaporation pure and simple, but chiefly assumes the special characteristics requisite in cases in which the formation of high-class sugar crystals has to be effected within its confines. On the other hand, it should be clearly understood that the duty of a multiple

evaporator is confined solely to the concentration of thin cane juice to a density of, say, 30° Bé., thus merely preparing it for further and special treatment in the vacuum pan, within which the grain is formed.

Were a vacuum pan required merely to act as a single-effect evaporator to prepare the juice for the vacuum pan proper, it might be constructed as shown in Fig. 128, and

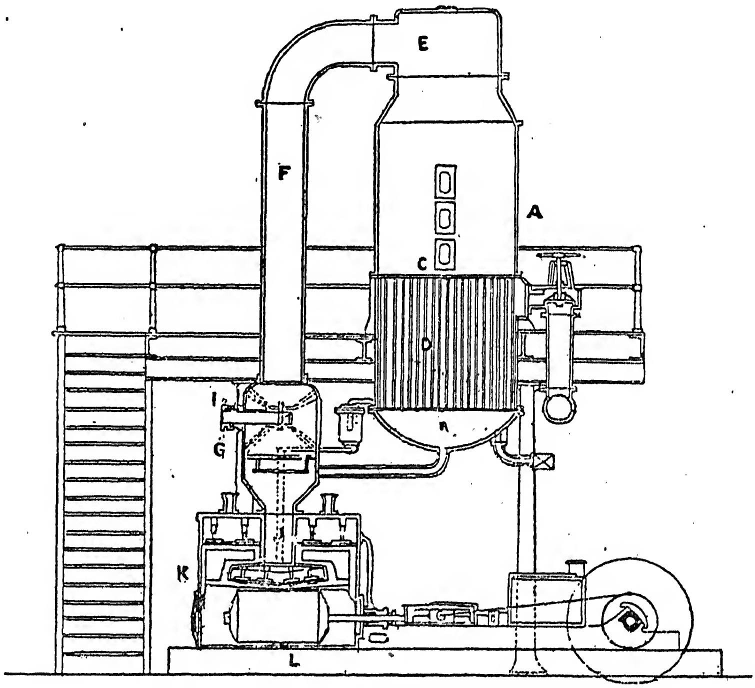


Fig. 128.—Section of a single-effect evaporator.

the partially concentrated syrup would subsequently be passed on to its successor for final treatment, resulting in the production of the sugar crystals. In Fig. 128, what is virtually a special form of vacuum pan is shown designed for the purposes of partial concentration alone. It acts as a single effect; and for each pound of steam used in its heating surface it will evaporate 0·89 lb. of water. The thin juice

is drawn into the space B of the vessel A, which it should fill up, before ebullition, to about half-way below the level of the upper tube plate C of the calandria or heating surface. Steam is turned on into the steam space of this calandria D, and evaporation takes place, the resultant vapour rising into the upper portion of the vessel and collecting in the dome E. It now passes downwards, through the capacious vapour pipe F, to the condenser G, where it meets with an inrushing stream of cold water, which enters the condenser through the rose-pipe H. It is thus condensed, and the mixed air and water fall down through the pipe J, into the suction chamber K of the vacuum pump L, which discharges its contents against the atmospheric pressure. This vacuum pump is of the displacement type, and in this case is seen in the rôle of a "wet" or "drowned" air-pump, thus dealing with and voiding the entire contents of the condenser. It maintains, moreover, a vacuum of some 26 or 27 inches of mercury in the body of the evaporator, and so enables the work of evaporation to be performed at correspondingly low temperatures without harmful contact with the external atmosphere.

In such an apparatus would be found embodied nearly all the conditions and requirements which, in the light of experience and scientific attainment, provide for the satisfactory single-effect evaporation of the bulk of the water in the cane juice, with minimum injury to the physical properties of the latter. It is, however, saddled with a serious drawback. As already observed, this form of single-effect evaporator is wasteful of steam and therefore of fuel. The heated vapour which rises from its boiling contents is lost for further practical use, being artificially and wastefully cooled in the condenser, and subsequently either sent to the cooling tower or thrown away by the pump into the factory drainage channels.

It was the utilisation of this wasted vapour which Rillieux effected, applying the principle embodied in the earlier high-pressure multiple evaporators already referred to. To put this improvement into practical shape, an additional and second vessel, M, is placed in advance of the original vessel A (Fig. 129), the thin juice first entering

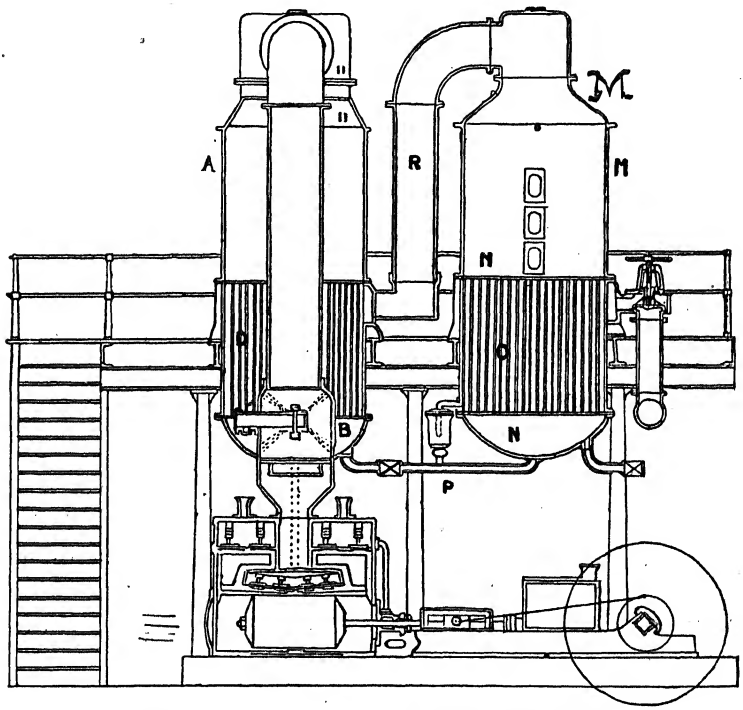


FIG. 129.—Section of a double-effect evaporator.

the juice space N, and the live steam the calandria O of this additional vessel, while a transmission pipe, P, enables the juice to pass from M to A at a fixed rate of transit. In this amplified form, or double effect, the initial steam, operating in the calandria O, boils the thin juice in the space N of vessel M, and the vapour from the boiling contents, collecting in the dome, passes down the vapour pipe R, which

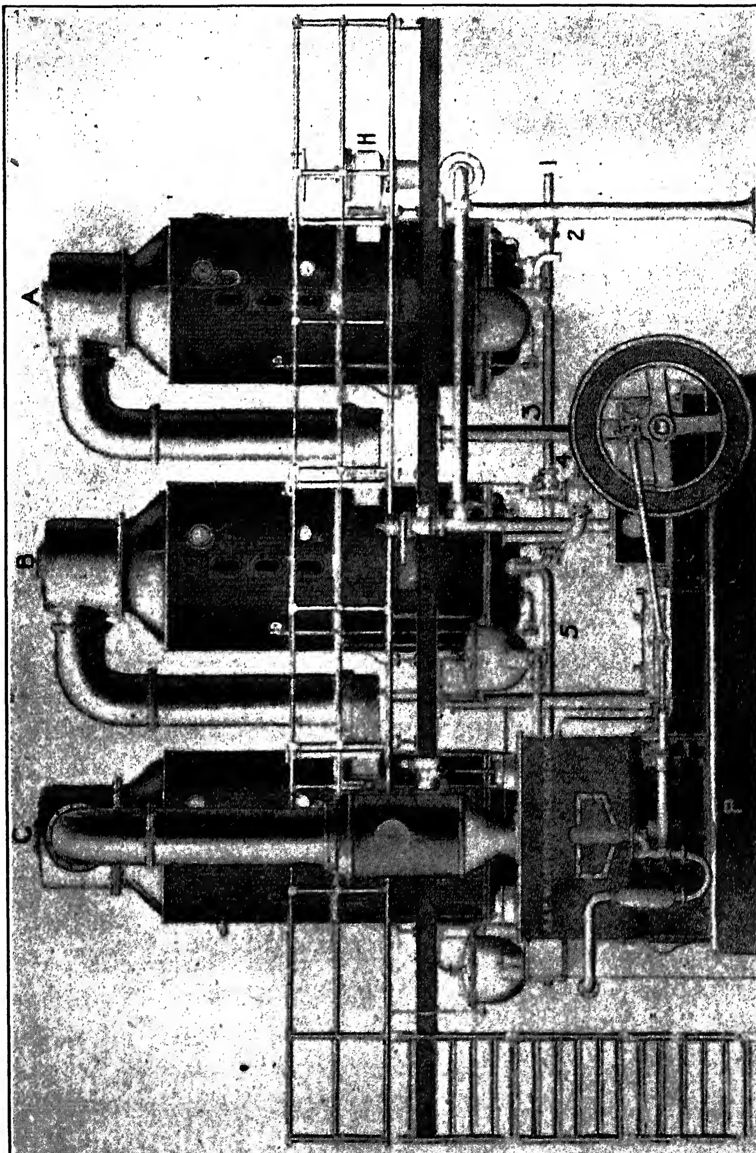


FIG. 130.—Exterior elevation of a triple-effect evaporator.

leads into the calandria D of vessel A, where it is not wasted, as before, but employed to evaporate still further the water from the already partially concentrated juice which has been withdrawn from the additional vessel, and has thus filled the juice space B of vessel A, the condenser and vacuum pump in connection with this vessel taking effect as formerly. By these means 1 lb. of steam can be utilised to evaporate 1·8 lb. of water. This explanation also serves to describe the fundamental principle upon which all fuel-saving multiple-effect evaporators are based, to whatever point they are extended and in whatever form they are found, whether as quadruple, quintuple, or sextuple effects.

In the concentration, however, of cane juice, which ultimately forms a more or less viscous syrup, and should be boiled at the lowest temperature possible, it is rarely considered advisable to employ more than three or at most four vessels, so as to avoid an initial high boiling-point, the lower number of three effects being most frequently in use. A triple effect and its working will therefore be now more fully described; and as it is customary to term the vessel which first receives the thin juice and the initial steam the "first vessel," this order will henceforward be used.

Fig. 130 is an exterior view of such an apparatus, while Fig. 131 is a section of the same plant. The thin juice enters the juice space D of the first vessel A, through the supply pipe 1, which is controlled by the valve 2. Later on it passes from the first vessel through the pipe 3, under control of the valve 4, into the juice space E of the second vessel B, ultimately proceeding, via the pipe 5 and the valve 6, into the juice space F of the third vessel C.

When first beginning to work the effect, the three vessels are each filled up to a suitable level with the thin juice, the several densities of the latter, in the respective vessels, reaching the correct point after the evaporator has been at

work a short time—the vacuum pump P having previously been started in order to create a vacuum in the three bodies, by means of which the juice is drawn into the apparatus. Steam is then turned on into the calandria G of the first body A, via the steam pipe and stop-valve H, and this is the only point at which steam enters the effect for the purpose of boiling the juice. The section clearly shows how the steam gains entrance to the calandria G, and how

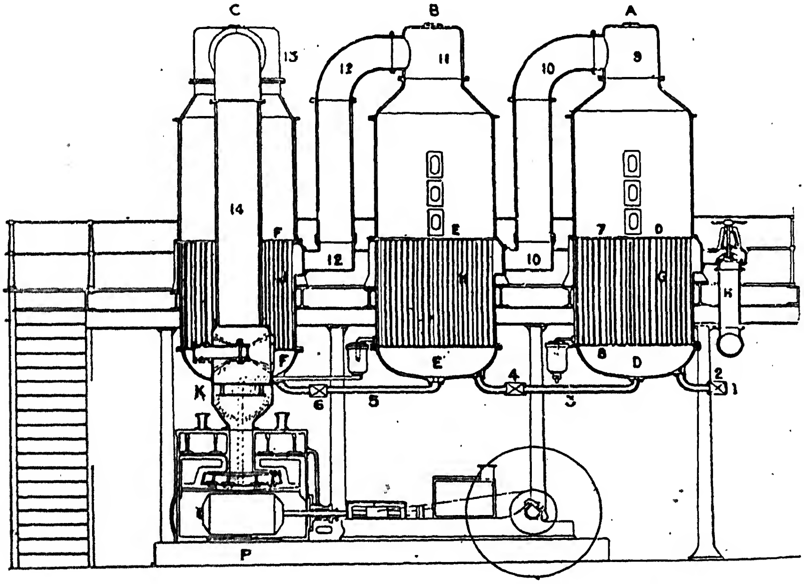


FIG. 131.—Sectional elevation of a triple-effect evaporator.

it will surround the exterior surfaces of the numerous tubes contained in the body and fixed between the upper and lower tube plates, 7 and 8, of the calandria.

A consequent boiling and evaporation of the juice take place, and the vapour from it rises through the upper portion of vessel A into the dome 9, whence it proceeds via the vapour pipe 10 into the calandria H of the second body B. This vapour thus causes the juice in the space E

of the second body B to boil also at a reduced temperature, under the reduced atmospheric pressure which obtains in this vessel. In the same way the cooler and more attenuated vapour from the denser juice in B rises into the second dome 11, and, passing down the vapour pipe 12, enters the calandria J of the third body or vessel C of the effect. Here the boiling of the still denser juice in the juice space F of this vessel takes place under an increased vacuum; the vapour therefrom, rising into the third dome 13 and passing down the vapour pipe 14, enters the condenser K, where, as already explained, it meets and is thoroughly intermixed with the inrushing stream of cold water, and is condensed on its way to the pump P.

It will be noticed that the steam acting at one end of the apparatus can itself proceed no farther than the confines of the first calandria G, and that the vacuum pump at the other end can only act directly via the condenser K and the vacuum pipe 14 upon the interior space of the third vessel C. These two working agents of the complete apparatus nevertheless act indirectly in opposite directions from end to end of its interior by virtue of the transmission of heat due to the one agent, and by the range of vacuum and gradual reduction of temperature steadily maintained by the other. When the triple effect has been brought into full action, and has been adjusted to the proper point of continuous working conditions, the following stages of approximate temperatures and vacua will be found to obtain in the various divisions of the complete apparatus: the initial temperature, due to the steam-pressure of some 5 lbs. per square inch in the calandria G of the first vessel A, will stand at, say, 228° Fahr., while the final temperature in the juice space F of the third vessel C will stand at, say, 126° Fahr., in conjunction with a vacuum of some 26 inches of mercury. The total range of temperatures throughout

the entire apparatus, which represent its capability for effective work, is thus seen to be about 102° Fahr., and this difference between these two extremes, subject to certain desirable limitations, should be maintained at as high a figure as possible. These limitations are unavoidable with regard to this point, for, on the one hand, excessive initial temperatures must be avoided for fear of injury to the juice; while, on the other, the capacity of the vacuum pump (an important factor controlling the amount of vacuum obtained in the condenser) must for economic reasons be kept within reasonable bounds. Turning attention to the other divisions of the apparatus, it will be found that the temperature in the juice space D of the first vessel A is about 208° Fahr., in conjunction with a vacuum of some 2½ ins. mercury; and approximately similar conditions should exist in the calandria H of the second vessel B. In the juice space E of the second vessel B the temperature will stand at, say, 180° Fahr. and the vacuum at about 14½ ins., similar conditions obtaining in the calandria J of the third vessel C. The following tabulated statement of the above figures will enable them to be more clearly understood:—

	First Vessel.	*Second Vessel.*	*Third Vessel.*
Temperature in calandria ..	228° Fahr.	208° Fahr.	180° Fahr.
Temperature of vapour ..	208° Fahr.	180° Fahr.	126° Fahr.
Vacuum in juice space ..	2½ ins.	14½ ins.	26 ins.

Under the above conditions and methods of working, the cane juice is not only more or less protected from the damaging influences of prolonged excessive heat, but also from exposure to the equally injurious effects of prolonged contact with the atmosphere. Moreover, fuel economy is promoted, and one pound weight of steam is rendered capable of evaporating 2·75 lbs. of water, as compared with the evaporation of, say, 0·89 lb. water per pound of steam

in an ordinary vacuum pan, in which the evaporation is by single effect.

Exhaust steam from the high-pressure engines of the factory is the heating medium used for a multiple effect. Mill and vacuum engines supply a considerable amount of this agent, and, even after use for the initial heating of the juice, there is usually more than enough available for the purpose, although the supply has sometimes to be augmented by high-pressure steam, administered under the control of a reducing valve. The pressure on the first or steam calandria, as already indicated, should not be more than 5 lbs., and is preferably less, corresponding to 228° Fahr., while the temperature of the condenser is usually in the neighbourhood of 126° Fahr. It should, however, be noted that the 102° of difference between these extremes, on which the work of the evaporator depends, is not evenly divided between the vessels, a characteristic division in the case of a triple effect being—

Between steam calandria and second calandria	20° Fahr.
Between second calandria and third	30° Fahr.
Between third calandria and condenser	52° Fahr.

Altogether satisfactory explanations of the cause of this apparently anomalous subdivision of temperature are wanting; but increased difficulty in the transmission of heat with the thicker syrup, and greater tenuity of vapour in contact with a unit of heating surface, are among the suggested solutions of the problem. The fact, however, remains that evaporators constructed with different-sized vessels show similar relations of temperature.

The juice, clarified in the manner already described, is drawn or gravitates into the first vessel of the evaporator, and, after a due stay there, passes on to the next vessel, and so on. By judicious setting of the supply cocks, or by

the use of equilibrium valves, the apparatus, when once started, may be made to work automatically, the gauge-glasses and peep-holes, with which the vessels are fitted, indicating the proper amount of juice contained in them. For the best results it is essential that only so much of the juice be present in each vessel at a time as shall be sufficient just to cover the upper tube plate, when the juice is in a state of ebullition. The juice, if undiluted, enters at a density of 10° Bé., or thereabouts, and requires, as already mentioned, to be concentrated to 28° or 30° Bé., before it is ready for the crystallising stage in the vacuum pan. When the proper density has been arrived at—and this can be ascertained by examination of the contents of the last vessel by means of the sampling apparatus—the syrup is withdrawn by means of a pump, either independent or attached to the main pump engine. Here also, by careful regulation, the withdrawal may be made continuous.

The main points on which the success of a multiple evaporator depends are—

(1) Adequate vacuum pump power.
(2) Large vapour connections.
(3) Rapid circulation of the juice over the heating surface.
(4) Complete removal of the condensed water, air, and gases.

As regards (1), there are in practice economic limitations to the height of vacuum in the last vessel of the effect. Although, speaking generally, a high vacuum is very desirable, it may be that the cost of obtaining, through its means, a high evaporating duty from the heating surface, may be such as to render an effect with larger vessels and comparatively low pump power a more economic apparatus. When, however, increased power is required with an evaporator already constructed, which has been working

with, say, a vacuum of 25 inches in the last vessel, by substituting a pump, which will maintain a vacuum of 27 inches, additional work will be obtained in the way of evaporation which would probably justify the alteration. This is especially the case with "bulk" evaporators, the greater difference in temperature thus obtained materially assisting the circulation of the juice over the heating surface.

(2) Large Vapour Connections.—In constructing an efficient multiple evaporator, one of the primary points to be kept in view is that facility of access of the vapour from one vessel to the heating surface of the next should be provided. Any constrictions or baffles, calculated to retard the passage of the vapour, at once detract from the efficiency of the heating surface, and high duty of the latter means proportionately large vapour connections as well as pump power. The theoretic maximum of effect is obtained when the heating surface is in immediate and complete contact with the vapour of the preceding vessel; and, in practice, as low a velocity as 50 feet per second for the vapour in the connections is aimed at for the first and second vessels. Another important factor in the well-doing of an evaporator lies in the immediate distribution of the incoming vapour over as large as possible a proportion of the heating surface.

As regards (3), rapid circulation of the juice over the heating surface is an important feature in evaporation. Up to a certain point—36 feet per second—the more frequent the contact of fresh portions of liquor with the heating surface, the more rapid is the transmission of heat through it, and the freer the escape of vapour from its constant movement. To provide circulation, it is customary in a standard evaporator to place in the centre or to one side of the drum a large pipe, 12 inches and upwards

in diameter according to the size of the evaporator. The effect of the boiling of the juice in the small tubes leads to an upward flow in them which concentrates in a downward flow through the large centre or side tube, a circulation being thus set up in the direction of the arrows (Fig. 132)

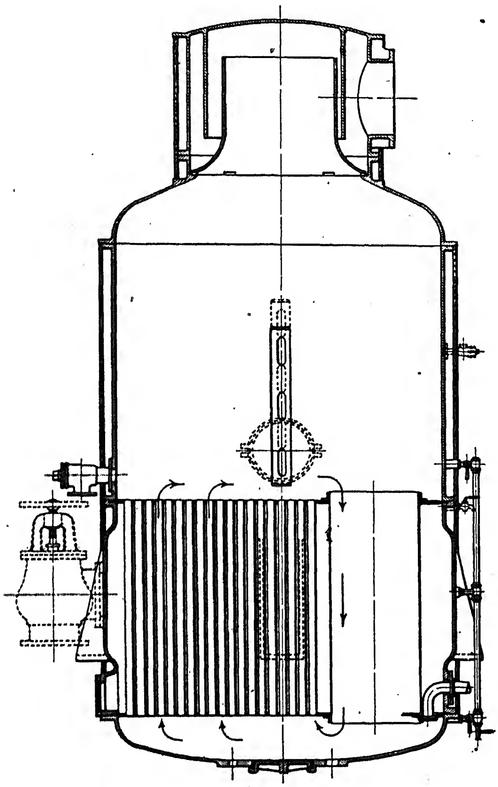


Fig. 132.—Sectional elevation of one vessel of a triple effect, showing the circulation of the juice through the small tubes and large side tube.

which materially assists evaporation. In some evaporators, called on this account "film" evaporators, this circulation is carried out mechanically by special pumps, and these are so arranged that a mere film of juice is in contact with the heating surface. Too much stress cannot be laid

on the importance of this detail of working of an evaporator, and it may here be remarked that in an ordinary "bulk," as distinct from a "film," evaporator the work entailed in creating the circulation may be regarded as being borne by and forming an important duty of the vacuum pump. In this way, a film evaporator may be looked upon as requiring less pump power than a "bulk" apparatus.

(4) Prompt removal of the condensed water is another essential to good work. In fact, the sooner the condensed water is removed from contact with the heating surface the better. It is generally brought about by the use of a separate pump or pumps; but when there is an excess of main pump power the calandrias are sometimes connected with the main pump, equilibrium valves being interposed to prevent the high vacuum of the latter drawing vapour from the calandrias as well as water. In cane-sugar works the vapour coming from the vessels contains a certain amount of air, which, unless removed, forms a cushion in the upper part of the calandrias which prevents contact between vapour and heating surface to the extent of the space occupied by the air. In the manufacture of Demerara sugar, also, volatile organic acids are liberated, and in the case of double carbonatation, ammonia, which if allowed to remain in the calandria bring about corrosive action. It is necessary, therefore, to remove all of them, and this is usually done by means of small pipes connecting the top of the calandrias with the condenser.

These small pipes are, however, usually insufficient in actual practice, and it is generally desirable, and a great convenience, to have several pipes, and of larger diameter, leading from the upper tube-plate of each calandria into the vapour space of each succeeding vessel, such pipes being under the control of an external valve for the purpose of varying adjustments. Finally the last group of pipes in the

last vessel discharge, through a control valve, into the condenser. Some experts prefer that the whole of the incondensable gases should be promptly removed from each calandria direct to the condenser. This preference involves the risk of probable waste of useful vapour, more especially in cases in which a liberal use of these pipes is found to be advantageous, as is sometimes the case.

In dealing with these four principal points, which are essential to the successful working of a multiple-effect evaporator, attention has so far been chiefly directed to matters which are especially connected with the design and construction of the apparatus, points which, once decided upon and carried into execution, permanently fix and characterise the conditions under which the evaporator will have to work. There still, however, remains another point of a practical nature which has to be very carefully attended to after the effect has been installed and set to work. This detail has reference to the great importance of keeping the entire heating surface in as thorough a condition of cleanliness as possible. There is invariably more or less scale deposited from cane juice during evaporation, and any neglect necessarily reduces the amount of work which might otherwise be performed by any given apparatus of a given size, and prevents the maximum transmission of heat throughout the respective calandrias. The importance of this matter directs attention to the desirability of arranging and constructing all details of the heating surfaces in such a manner as will ensure accessibility, and thus enable them to be readily cleansed when necessary.

In the remarks introductory to clarification, emphasis has been laid on the fact that efficient clarification has a most important bearing upon this point of maintaining a clean heating surface; for the better the clarification the less likelihood there is of an excessive deposit of scale in the

multiple effect. It is quite a reasonable assertion to say that, with satisfactory clarification, the effect should only require cleaning once a week, and that the amount of scale then to be removed will be of small quantity.

As already mentioned, the evaporation performed in a multiple effect is not only that due to the steam added in the first vessel, but also to the heat represented by the difference in the temperature between the ingoing hot juice and the resultant cooler syrup. The amount of evaporation done by the several vessels would therefore apparently increase as the series progresses, and on this account, and for other reasons too technical for this work, the heating surface should theoretically be proportioned to meet this condition. In fact, some years ago triple effects were occasionally made with vessels sized in this manner, generally in the proportion 4 : 5 : 6, as regards heating surface. These, for their 15 units of heating surface, did as much evaporation as an equal-sized vessel evaporator with 18 units. This advantage has not, however, been considered as balancing the extra cost of construction involved, and modern evaporators are generally made with equal-sized vessels.

An important advantage may, however, be taken of this uniform size of all the vessels, and the consequent theoretically excessive size of the first vessel, to heat the juice coming from the mills on its way to the clarifiers by withdrawing into a special heater the excess vapour available for extra use in the juice space of this first vessel.

By such use some preliminary heating of the cold juice is effected by double effect, and by this method, if not carried out to excess by robbing the first vessel of vapour that should properly be carried forward to the succeeding vessel of the effect, excellent results can be obtained coupled with fuel economy. Furthermore, better working conditions

and increased work are maintained in this vessel. Similar heaters may likewise, and for similar reasons, be attached to each and every vessel of the effect.

To carry out this system of juice-heating to its fullest extent at the multiple effect, the cane juice from the mills should first be brought direct from the strainers, or from the sulphuring apparatus to a specially designed heater placed between the last vessel of the effect and the condenser, such heater being of capacious size and of an open type, to be acted upon by the waste hot vapour on its way to otherwise wasteful condensation. If practicable, these effect vapours should be augmented by the addition of the waste vapours from the vacuum pans, which is more especially feasible in the case of central condenser installations. Here the juice will receive, more or less according to circumstances, an approximate increase in temperature of some 25° Fahr. to 35° Fahr., an increase of considerable importance to the low temperatures existing at this stage. It should then pass on to the above-mentioned heaters attached to the vapour spaces of the successive vessels of the effect, where it will receive a further increase in temperature of some 50° to 60° Fahr. Subsequently, at an accumulated temperature of from 160° to 180° Fahr., it will leave the effect heaters and be conveyed to a finishing heater placed near the clarifiers and heated by exhaust steam from the factory engines, where it will be finally raised to whatever temperature may be most suitable for the particular system of defecation employed. By these means the heating of the colder cane juice is effected in an economical manner, with highly beneficial results so far as steam consumption and fuel economy are concerned.

But although the vessels themselves are usually constructed of the same size, it is not so with the vapour con-

nections between the several vessels. As the temperature at which the juice boils is lowered by vacuum, the vapour from a given weight of evaporation increases in volume. Thus, 1 lb. of water vapour, at the atmospheric boiling-point, 212° Fahr., occupying 26 cubic feet, would give 53 cubic feet when the boiling-point was 177° Fahr., and 172 cubic feet at 126° Fahr. As the amount of evaporation in the several vessels is the same, or, if anything, increases as the series progresses, it follows that, to avoid constriction and consequent slowing down of the vapour flow, the areas of the vapour connections have to be proportionate to the increase in volume of the vapour to minimise such constriction and consequent retardation of contact between the vapour from one vessel and the heating surface of the next. Formerly, when the need of larger vapour connections was not sufficiently recognised, it was customary, for the sake of convenience, to construct them of equal sizes, but vapour connections are now usually sized to meet the foregoing conditions.

The work done by a standard triple, in proportion to its heating surface, depends upon the satisfactory fulfilment of the above requirements. With these fulfilled, at least 6 lbs. of water may be taken as the evaporation per hour for every square foot of heating surface. Up to twenty years ago, a duty of 3·5 lbs. of water evaporated was usually taken as a basis of construction in a standard triple; but a full recognition of the above indicated requirements has resulted in the better work represented by the former figure being obtained. It must, however, be borne in mind that the efficiency of an evaporator is influenced to a considerable extent by the quality of the juice being dealt with, the liberation of vapour from a juice containing a notable proportion of gums being much slower than from a pure juice. Note, again, the great importance of perfect clarification.

When erecting an evaporator of a more or less limited number of effects, room is sometimes left for additional vessels. Future extensions and improvements might call for the conversion of a double into a triple or even a quadruple effect, and the above provision would permit of this extension. Such alteration would have for its chief object the saving of fuel used in the work of concentration of the juice. Any increase or decrease in the amount of juice concentrated in a given time by the extended apparatus is an altogether separate question, and the result would largely depend upon the conditions under which the latter was worked subsequently to the alterations. The circumstance that the original vacuum pump would now proportionably be of increased power would offer a proportional facility for the attainment of a corresponding increase in the output of the apparatus when desired. On the other hand, the lessened differences of temperature between the several vessels would lower the efficiency of the heating surfaces. It may be said, however, that the conversion of a triple effect into, say a quadruple, would result in a reduction of fuel, and a slight increase in the amount of work done.

Fig. 132A gives an interesting section of a special form of quadruple effect of modern design, which is intended to provide for the definite and single passage of the juice once through the calandria tubes of each vessel in succession.

The standard evaporator, already shown, is represented with a condenser, the water from which is drawn away by the vacuum pump. In some instances, especially with evaporators of large size, the principle of a Torricellian vacuum is utilised (Fig. 133). In this, the vacuum is obtained by placing the condenser at a height above 34 feet from the ground water-level, the height of a column of

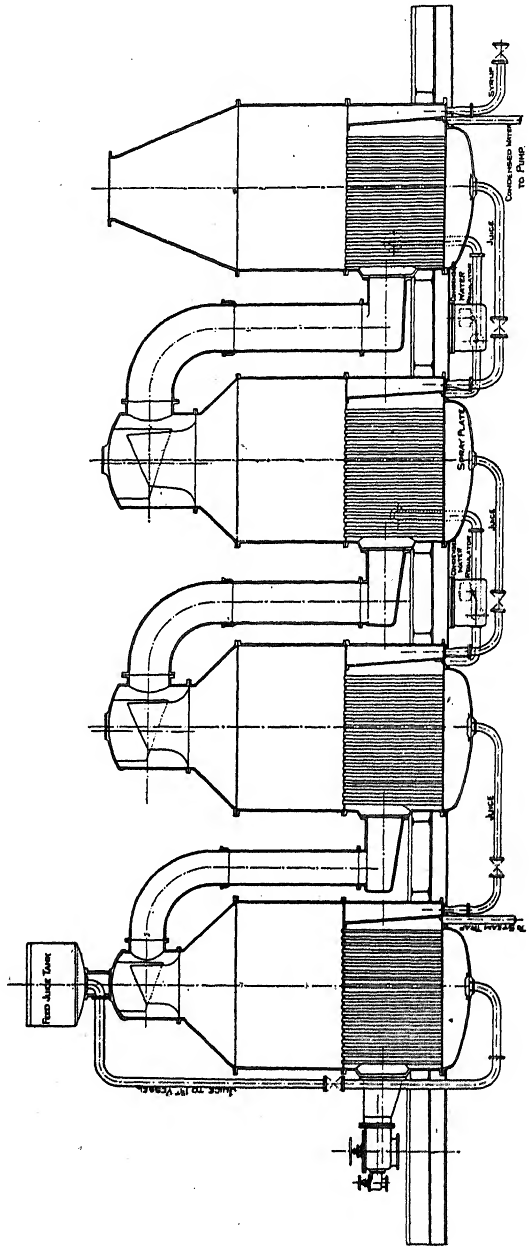


FIG. 132A.—Special form of quadruple effect.

water equivalent in weight to the atmospheric pressure. In this case the water does not require to be drawn away by a pump, but it is necessary to attach a dry vacuum pump to the upper part of the condenser, so that air and uncondensed gases from the juice may be drawn off, and the

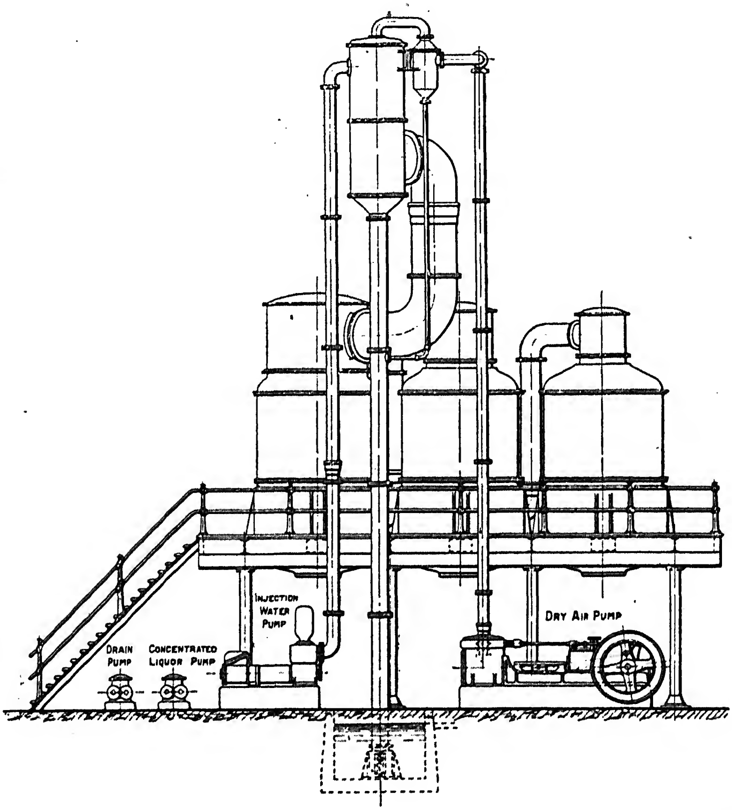


FIG. 133.—View of a triple effect worked in conjunction with a Torricellian condenser.

vacuum thus maintained. Both systems of condensation, as well as the pumps employed, are described in the chapter devoted to "Crystallisation."

A common fault with triples as formerly constructed and worked was that of "entrainment," or the carrying

over of juice automatically into the calandrias and condenser. This was due in great measure to the practice of working standard evaporators with too large a quantity of juice in them. It was commonly supposed that the juice level when at rest should be half-way up the lower spy-glass. This being so, the danger of juice being carried up into the vapour connections by spurting during ebullition, especially in the more viscid syrup of the last vessel, had to be guarded against by the introduction of baffles and various entrainment preventers in the head boxes of the several vessels. As evaporators are now usually worked, with comparatively small quantities of juice in them, the juice not showing a level higher, say, than half-way or even less up the calandria, the juice during ebullition only just covering the upper tube-plate, the danger of entrainment is considerably reduced provided the attendant can be relied upon at all times to maintain low and correct juice levels. In fact, it may be taken that if the essentials of construction are followed as already indicated, and if the evaporators are properly and carefully worked, the loss by entrainment is reduced to a very low figure. It must be remembered that most anti-entrainment systems have proved themselves to be consistently prejudicial, to a greater or less extent, to perfectly satisfactory conditions as regards vapour travel. Neither have they, in spite of most up-to-date precautions, been entirely successful in the complete stoppage of entrainment.

The most satisfactory way of dealing with this question of entrainment, both with regard to vacuum pans as well as multiple effects, is to abolish all corrective arrangements of obstructionary type, and grapple with the evil more immediately after the point of generation and more closely in harmony with the natural requirements of this troublesome situation. Speaking generally with reference to this

question of entrainment, in any evaporator, whether for water or cane juice, it is more efficacious to cope with the difficulty in the simpler and better way of the employment of vessels of increased height above the upper surfaces of the heating arrangements.

Theoretically, in the particular case of multiple effects, if the height of the bottom level of the vapour outlet at the top of each vessel be fully 10 feet above the level of the upper surface of the calandria, upper tube-plate (correct juice levels being steadily maintained) entrainment will not occur, and it is best to fix this height at not less than 12 feet, a height even of 14 feet being preferable. The calandrias and juice spaces of the respective vessels of the multiple effect remain unaltered in any respect, but the upper portions or vapour spaces of the vessels are thus considerably increased in height above the level of the calandria upper tube-plates. This is a simple and comparatively inexpensive extension which will promote all-round efficiency and satisfactory results, both as regards entrainment and increased output of the apparatus. This method of minimising any danger of entrainment does away with the employment of doubtfully efficient and complicated obstructions, and absolutely abolishes mechanical entrainment, though some experts are inclined to assert the continued presence of a very trifling and negligible amount of vesicular entrainment that may still occasionally occur.

It is frequently forgotten that the loss of sugar is not the sole consideration involved in this matter of entrainment. It also seriously affects the cleanliness and efficiency of the vapour side of the heating surfaces. The juice under treatment more or less fouls the inner surfaces of the heating tubes, whilst any sugar or other substances that may improperly be carried over by the vapour current

will foul the outer and more inaccessible surface of these same tubes. It is therefore important that the vapour from the juice spaces of the preceding vessels of any effect should reach the heating surfaces of the succeeding effects in as pure a condition as can be ensured by reasonable and effective arrangements. Similarly, it is desirable to separate any oil that may accompany the exhaust steam from the engines on its way to the multiple effect, and prevent its entry into the first calandria, and its subsequent deposition upon the outer inaccessible surfaces of the heating tubes. Of such consequence are these considerations that it is the practice on some estates, with the assistance of suitable apparatus, to withdraw and remove all the heating tubes from the effects during the recess between consecutive crops, and replace them after having thoroughly cleansed their outer as well as inner surfaces.

The quantity of sugar lost by entrainment is exceedingly difficult to estimate. With a good working evaporator the calandria water shows no apparent sign of juice contamination, a considerable quantity having to be concentrated before a trace is discovered. With an enormous bulk of the water flowing from the condenser, chemical detection is practically impossible. When, however, the water for condensation is constantly used again, the blackening of it denotes impregnation with sugar, although a great deal of this may be due to other matters boiled out of the juice rather than to sugar itself. It is extremely doubtful, however, whether the loss by entrainment in good evaporators, carefully worked, amounts to more than, if so much as, 0·25 per cent. of the sugar in the juice.

In a well-ordered cane-sugar factory, an important function of the evaporator is that of acting as a surface condenser to the engines. If the evaporator is powerful

enough to do the work of a factory with a nominal pressure of steam in the first vessel—1 to 2 lbs. on the square inch—the efficiency of the engines will be greatly increased; and it frequently happens that a worrying fuel account dis appears when an evaporator is installed sufficiently powerful to give this condition, even although its predecessor had been able to do the required concentration at a steam pressure of, say, 6 to 8 lbs. This again emphasises the importance of an evaporator being constructed to work freely throughout, free from constriction in vapour connections and baffles.

In the general description and explanation which has so far been given of the design and manipulation of a multiple effect, reference has been confined to bulk evaporators fitted with heating surfaces in the form of submerged vertical tubes contained in vertical vessels. In such apparatus the tubes are permanently fixed in the tube plates, are of a comparatively large diameter, and rarely exceed a length of some 5 feet. As already mentioned, the boiling cane juice is contained and circulates within the tubes and juice space of each vessel, while the heating agent, in the form of vapour, acts upon the exterior surfaces of the former. Nowadays there is a tendency, within reasonable limits, to keep these heating tubes as large in diameter and as short as possible, with a view to avoid any throttling of juice circulation, as well as to facilitate the operation of cleansing the interior surfaces from accumulations of hard scale, which are very liable to form on them, and affect their efficiency as effective transmitters of heat. It is therefore desirable, before attempting any description of the various forms which such apparatus have assumed, to point out that, when preferred, bulk evaporators can be used which are composed of horizontal vessels furnished with submerged horizontal steam tubes. Figs. 134, 135, and 136 give

particulars of such an installation. It will be seen that in such cases there are considerable modifications in the arrangements connected with the heating surface. The

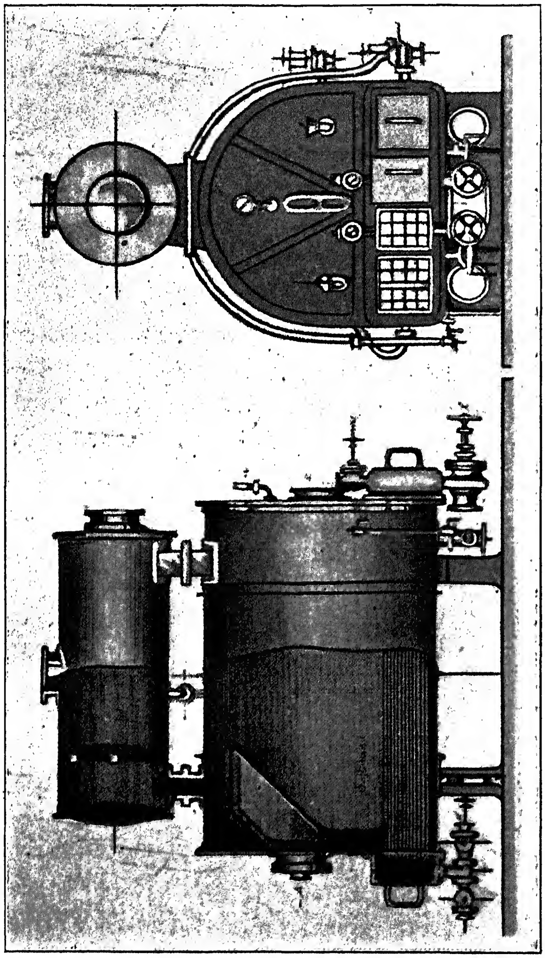


Fig. 134.—Side and end elevations of one vessel of a horizontal effect.

juice surrounds the exterior surfaces of the tubes, and lies wholly amongst them, as well as in the lower spaces of the vessels which are adjacent to these tubes. The latter are removable, instead of being permanent fixtures, and, as

steam circulates through them in place of juice, it is permissible to make them fully double or treble the length of the vertical tubes. They are, moreover, usually of a much smaller diameter, and are generally arranged in vertical batches or nests of varying widths of some six to nine tubes per width of nest. The steam usually makes some three passages backwards and forwards through the horizontal mass of tubes, passing first through the centre of the mass, the cooler and wetter steam leaving the calandrias via the last batches of tubes located nearest the sides of the vessels. A definite juice circulation is thus promoted, which takes

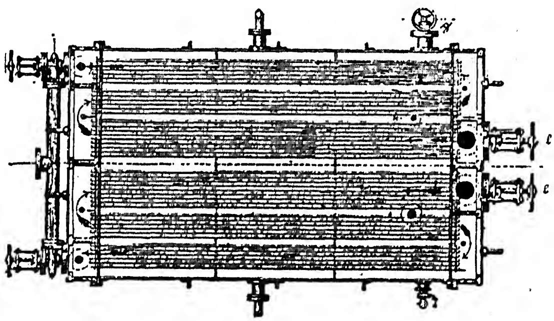


FIG. 135.—Plan of one vessel of a horizontal effect.

effect in an upward direction in the central and hotter regions of the vessels, while a continuous downward current obtains towards the sides. When the tube surfaces become coated, as they will do, with deposits of varying description, they can be entirely removed from their working positions, thoroughly cleaned both inside and out, and restored to their places in such a condition as will secure maximum efficiency. It will be seen from these illustrations that the general proportions and shapes of the vessels comprising the horizontal effect are totally different from those of a vertical effect, and offer certain conveniences and advantages which are available for use wherever they may be

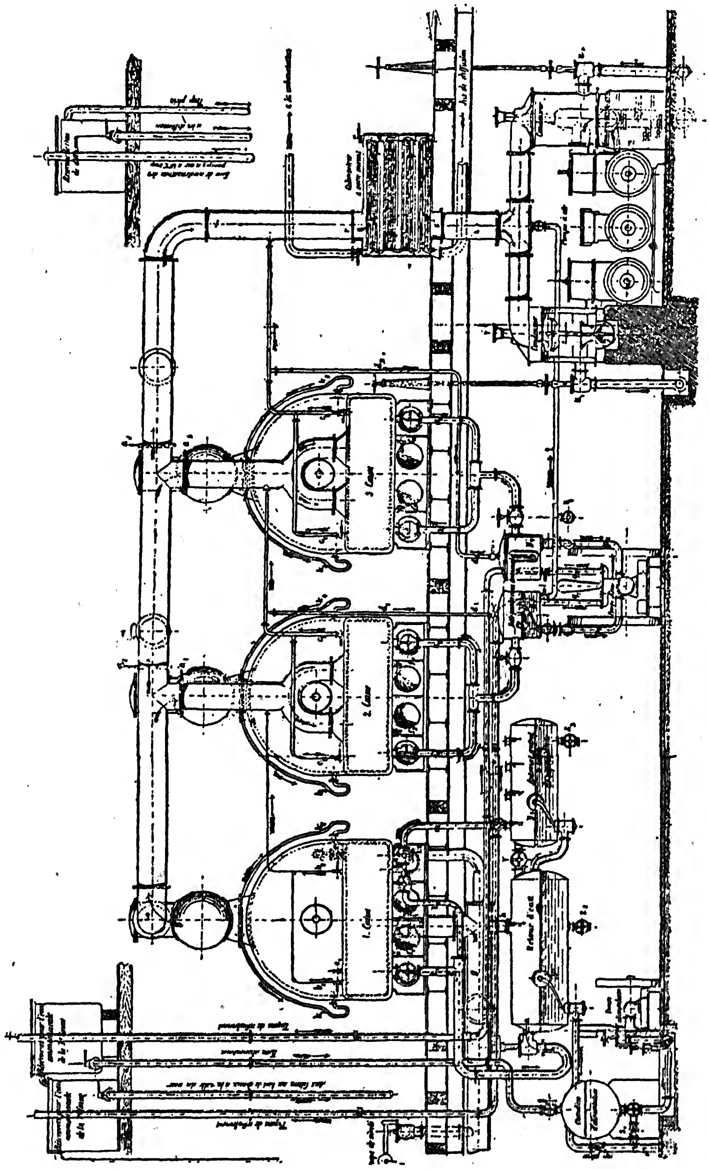


FIG. 136.—General arrangement of a horizontal effect.

preferred. Referring in general terms to the methods of construction and employment of these respective types of

evaporators, it may be said that all the points emphasised above, with reference to the vertical apparatus, apply with equal force to the horizontal.

In proceeding to describe the various forms of vertical and horizontal evaporators, which from time to time have been offered for the use of sugar manufacturers with a view to promote increased efficiency in this section of the process, it should be remarked that they may approximately be divided into two classes—" bulk " and " film " evaporators, and will be dealt with under these two divisions.

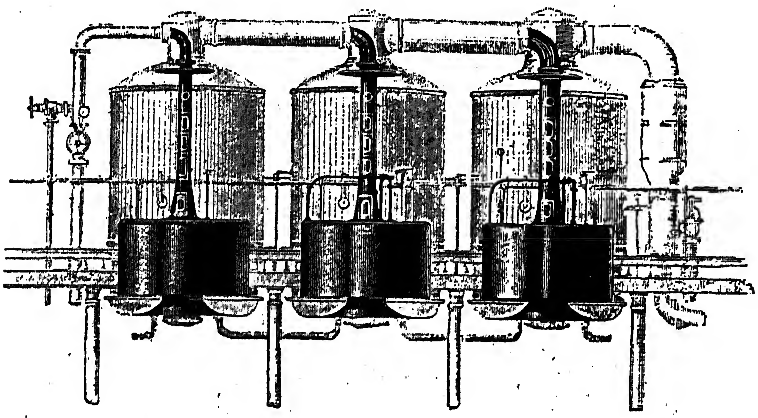


FIG. 137.—Elevation of the three vessels of a vertical triple effect fitted with suspended calandrias.

One of the first modifications to be noticed is shown in Figs. 137 and 138, and has reference more especially to the particular form of calandria employed. The first of these illustrations demonstrates the manner in which the heating surface is arranged, and the characteristic means employed in introducing the steam and vapour into the respective calandrias. These heating agents, in this case, enter the dome of each vessel, and pass downwards to each calandria through a vertical internal pipe to the centre of the calandria drum, the centre inner tube being arranged to dis-

tribute the steam or vapour equally and radially throughout the entire drum. An upward circulation of the juice is thus promoted through the vertical tubes, and a corresponding downward movement results in the annular juice space existing between each calandria and the inner surface of the vessel in which it is placed, the maintenance of this current being further facilitated by the special shape of the lower covers of each vessel. These covers are also furnished with a raised flange upon which the drum is fixed and sup-

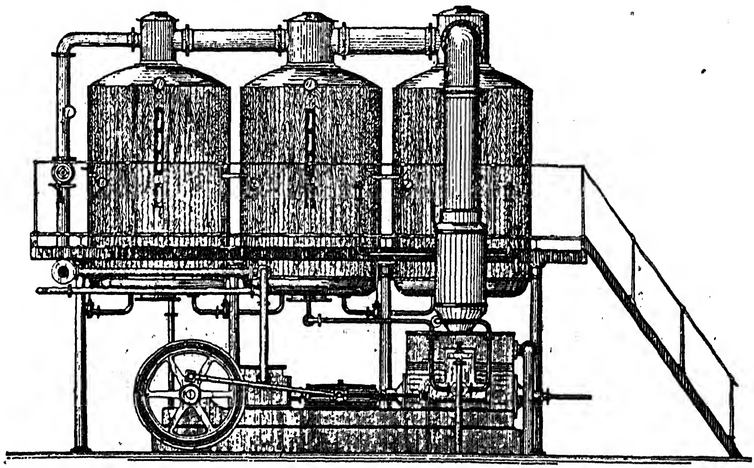


FIG. 138.—External longitudinal elevation of a triple effect fitted with suspended calandrias.

ported, and the latter, when required, can be lowered to the ground for the purpose of examination and for repairs. It is claimed for this special form of calandria that the increased difference between the temperature of the rising juice in the tubes and the cooler descending liquor in the annular space, combined with the special shape of the cast-iron bottom attached to each vessel, promotes a much higher rate of circulation than is obtained with the original form of calandria, thus increasing the efficiency of the heat-

ing surface. If Figs. 130 and 138 are compared with each other, it will be perceived that the adoption of the above system of internal steam and vapour pipes effects a considerable difference in the external general appearance of the respective apparatus. The three vessels of the later type are closer together than formerly owing to the absence of two of the large down-take vapour pipes, which are replaced by large-sized horizontal connections fixed between the domes of the three vessels. In other respects this modified apparatus is very similar to an ordinary standard triple effect, as already described, and there is no difference in the methods employed in its manipulation, or in the general laws which govern its efficiency.

Another form of triple effect which should next be noticed is shown in Figs. 139, 140, and 141. While the form of construction of the apparatus last described had reference more particularly to the special disposal of the heating surface, and the particular route by which the steam or vapour is led to each calandria, the type of evaporator now to be dealt with is more especially designed with a view to ensure the freest possible passage of the heating medium into the respective calandrias through which it has to act upon the fluid in contact with them. Similar care is devoted to the means devised for the prompt removal of the condensed vapour which would otherwise collect in the form of water in the lower portions of the latter, important requirements upon which stress has been laid in an earlier portion of this work. The reference letters in the three illustrations suffice to define the relative positions of the component portions of the apparatus in plan and elevation respectively, and it may be mentioned that during the period previous to the evolution of this particular design of evaporator, it was a common practice to pay insufficient attention to the defects which it is in-

tended to eliminate. Taking Fig. 140 more especially into consideration, but coupling with it the two elevations, it will be perceived that the initial steam is first of all admitted to the calandria of the first vessel through a stop-valve of ample size, which, through the agency of an equally capacious double-branched pipe, delivers this steam at

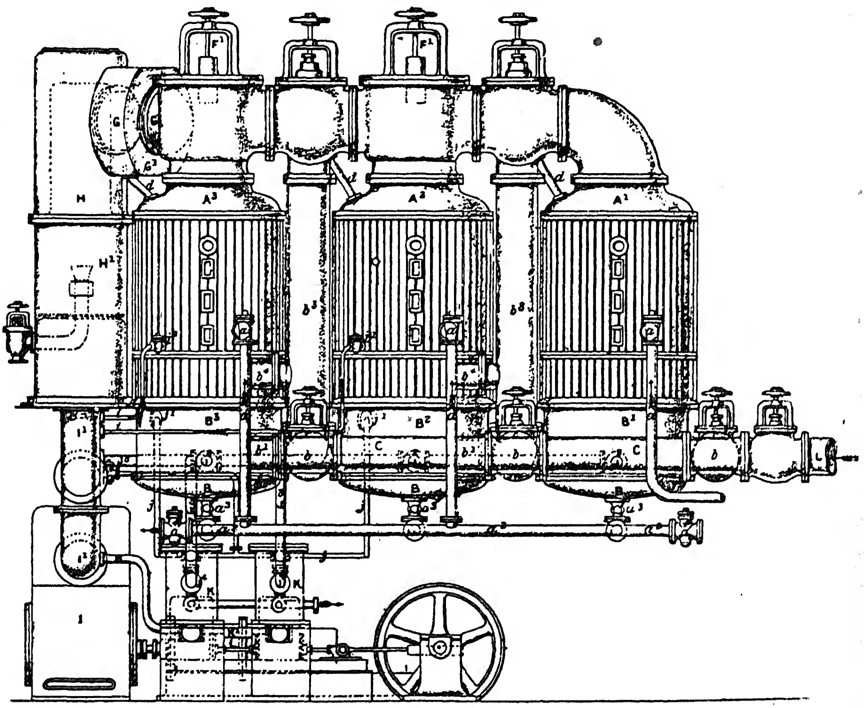


FIG. 139.—Exterior longitudinal elevation of a vertical triple effect fitted with isolation valves and double vapour connections.

two points within the calandria. Vigorous boiling of the juice in the first vessel is thus ensured, and the resultant vapour rises into a large dome through which it proceeds to a roomy steam box. Thence it passes downwards through two large vapour pipes on its way to the second calandria, to which it is admitted, as in the case of the steam and the

first vessel, at two points. A similar and equally ample provision is made for the passage of the vapour from the juice in the second vessel as it proceeds on its way to the third calandria, while the resultant vapour leaves the third vessel through a short passage of large diameter into the large condenser, in which it is condensed on its way to the

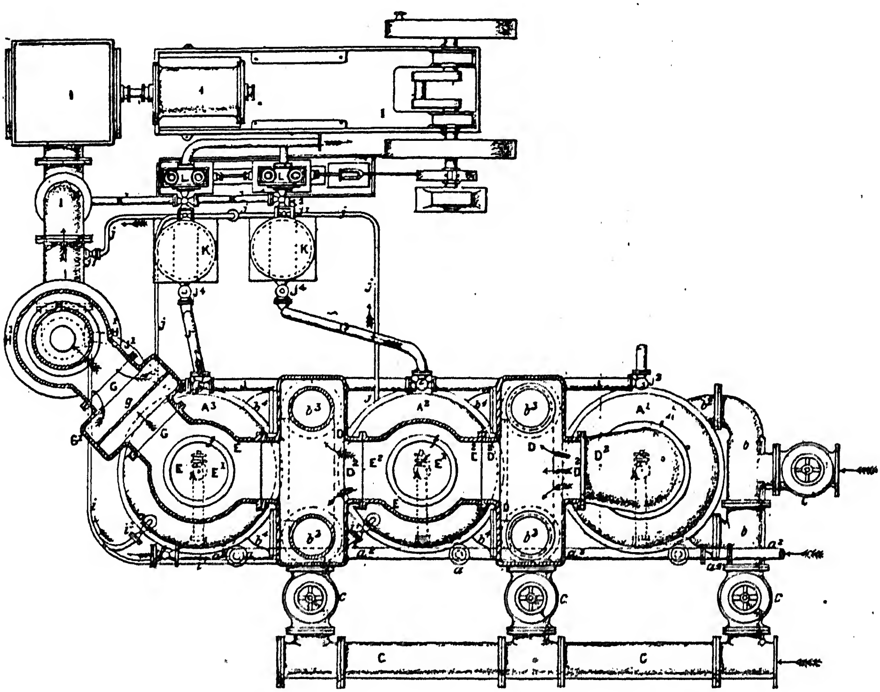


FIG. 140.—Sectional plan of apparatus shown in Fig. 139.

vacuum pump. The illustrations explain the details. It will also be seen that facilities are provided for working this evaporator either as a single, double, or triple effect, a convenience which is regarded usually as a luxury rather than a necessity, and is a doubtful advantage in view of complications, though it may be made use of to facilitate the boiling-off of the liquor when the work of the factory is

finished. However, the completeness of the above arrangements is very marked; and so much having been provided in the first instance to ensure the efficiency of the heating surface, it remains, in the second instance, to guard against

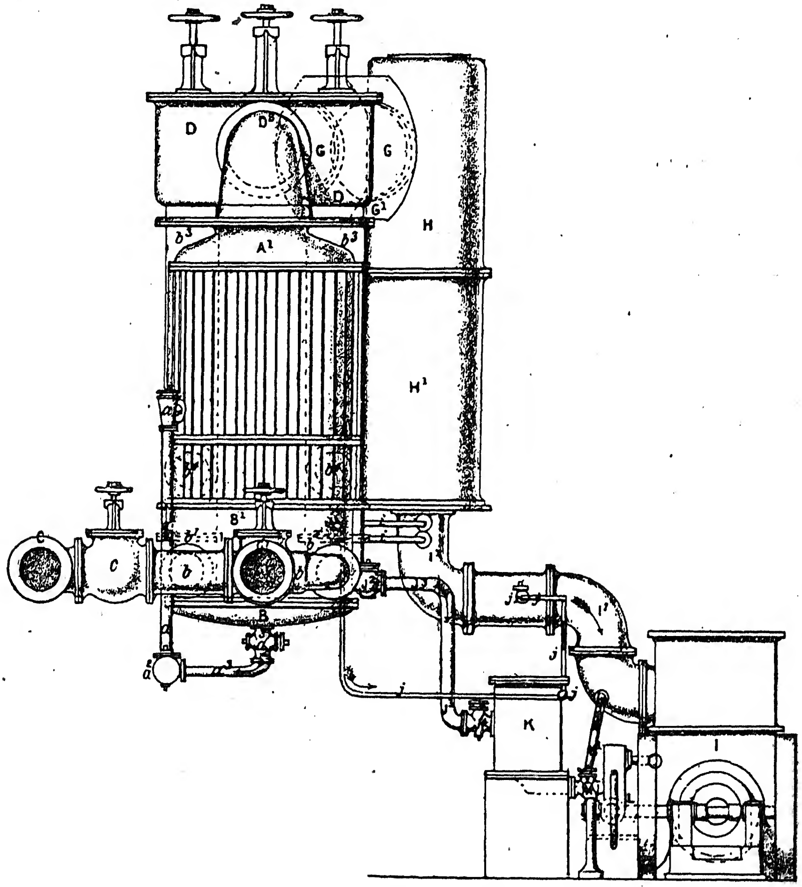


FIG. 141.—End elevation of apparatus shown in Fig. 139.

the accumulation of condensed steam and vapour in the respective calandrias, which would otherwise nullify the ultimate efficacy of the above provisions. Each calandria is in itself a condenser, and the condensed vapour which is

forced or withdrawn from each division of the total heating surface is a fairly correct measurement of the work done by the respective sections of such surface. As the calandria of the initial vessel is worked under pressure, it is sufficient to furnish it with an efficient form of steam trap of ample size, which, when it is properly arranged, will serve thoroughly to drain it of all condensed steam without permitting the escape of uncondensed vapour. This resultant hot water is caught in a tank and used towards the make-up of feed-water for the factory boilers. In the case of the second and third calandrias, varying degrees of vacuum complicate matters; and as the accumulating water cannot escape without assistance, it is necessary to connect a separate pump to each of these sections, which in their turn ensure efficiency. Water receivers, K, are attached by suitable connections, J and J[3], to the respective calandrias, to collect the water flowing from the latter; and these receivers are usually fitted with mechanical devices which prevent the withdrawal of uncondensed vapour along with the water. Two small calandria pumps, L, of calculated sizes, are worked by the main vacuum-pumping engine, as seen in the illustrations, and finally withdraw all the available contents of the receivers. A passing reference has already been made earlier in this chapter to the function of these accessories, and this opportunity is taken of giving a more detailed account of their surroundings and to explain them and their duties more fully.

The hot water withdrawn by the two last-mentioned pumps should not be used as a make-up feed for the steam boilers. It is necessarily more or less contaminated with organic vapours which are liable to destroy the tubes and plates of the boilers. They need not, however, be wasted, but may be employed for the purposes of the saturation of the megass on its passage from cane mill to cane mill, and

by this means the available heat units are not altogether lost, but are usefully employed in imbibition and maceration, and ensure hotter and better megass fuel at the boilers. Chemical experts must be left to decide the respective merits of the use of hot or cold water for this purpose, but so far as the engineer is concerned, it is an important advantage to use this acidified water as indicated above, such use very considerably improving the physical characteristics of the megass to be used at the boiler furnaces.

From the foregoing description, it will be seen that the necessary care and attention have been devoted to such provisions as will enable one of the operative agents of a multiple-effect evaporator efficiently to do its duty, and, so to speak, get at its work in the very first instance. It, however, explains but one of the three main conditions which must be carefully promoted and obtained if modern evaporators are to yield maximum results. The heating agent may now, in the above case, be said to be in a satisfactory position to perform its initial duties; but it requires the co-operative assistance of the two other conditions if its powers are to be employed to the fullest extent, viz. a perfect circulation of the juice—the subject to be operated upon—and the satisfactory maintenance of a sufficient vacuum. Turning further attention to the circulation of the juice within the respective vessels, it will be noted that Fig. 137 gave details of one method which has been devised to promote a complete diffusion or rapid and continuous passing of the body to be acted upon over the heating surface; and Figs. 142 and 143 give particulars of further contrivances arranged for this purpose. They also show that proper attention has been paid to the free passage of the vapour from vessel to vessel, and to its complete and ready arrival amongst the mass of tubes upon the exterior surfaces of which it has to act.

Fig. 142 shows a section of the first of the three vessels of a triple effect. The initial steam enters the supply pipe at 2, and divides into two streams, a and a', finally entering the calandria through the splayed rectangular openings a'', which serve to distribute the stream promptly over as wide a portion of the exterior surfaces of the tubes as

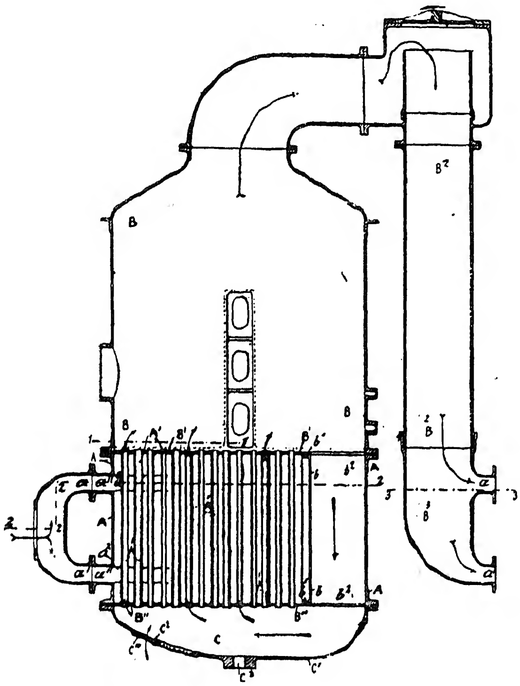


FIG. 142.—Sectional elevation of one vessel of a vertical triple effect fitted with segmental calandrias.

possible, the drier steam taking the upper course, the wetter the lower, this division of the main current beneficially affecting the juice circulation. Fig. 143 gives further details of the shape of these splayed inlets, and, moreover, indicates that certain of the heating tubes of the calandria are purposely omitted from their customary positions in order to give the incoming steam freer access to the in-

terior of the calandria. An upward and rapid juice circulation is thus established in the tubes as indicated by the arrows, and the fluids are propelled from the hotter regions of the vessel, where the steam is first admitted, towards the cooler side, and descend to the lower juice space *c* by means of the capacious down-take b^2. This down-take is left as a free passage-way by virtue of the curtailment of the

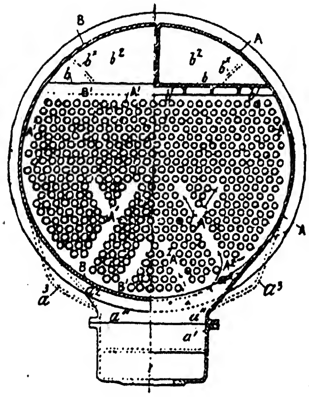


FIG. 143.—Plan of segmental calandrias shown in Fig. 142.

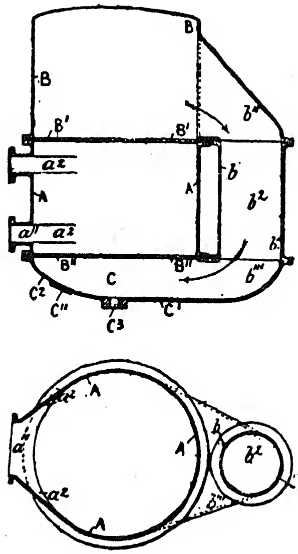


FIG. 144.—Sectional elevation and plan of one vessel of a vertical triple effect fitted with external juice circulating passages.

calandria heating surface for any given diameter of vessel, as will be understood more distinctly by an examination of Fig. 143; and, in passing, it may be remarked that similar results are obtainable by the arrangements shown in Fig. 144. Thus, if in any particular case it is important to make full use of the entire diameter of the vessel for heating surface, the down-take b^2 may occupy an external position, and this extension may be carried out in various ways,

either by means of attached castings or by suitable modifications or enlargements of particular portions of the vessel itself. The second and third bodies of this effect are virtually repetitions of the first vessel, due attention being paid to the conveyance and application of the more attenuated vapour which has to be accommodated. In this particular apparatus, single and extra large vapour down-takes, B^2, take the place of the double down-takes seen in Fig. 140, and there is no reason why this less complicated disposal of the vapour passages, coupled with ample splaying and spaciousness of the entrances to and the exits from these passages, should not conduce to maximum efficiency. The external appearance of this apparatus when at work is not altogether unlike that already shown in Fig. 130, which may be taken as giving a general but rough idea of its appearance.

In the case of each of the types of evaporators above described, the passage of the treated juice from vessel to vessel is controlled by means of valves which are located between the vessels; and by a careful regulation of such valves—as has already been pointed out—practically automatic movement of the juice throughout the entire apparatus can be arrived at. The condensed steam and vapour has, moreover, been promptly removed from each calandria through the agency of traps and pumps, such immediate withdrawal depriving the apparatus of the benefit of a certain amount of heat which, under different conditions, might have usefully been employed within these confines.

Figs. 145 and 146 show the principles which have guided the design of another form of these evaporators. This, with due appreciation of the desirability of a free removal of the water produced by condensation in the calandrias, and without at all impairing the necessary working con-

ditions which should obtain within them, also seeks to utilise such available heat as would otherwise be lost to the maximum efficiency when such condensations are at once removed from the apparatus. A free and uninterrupted circulation of the juice which is being treated throughout the various vessels, as well as from vessel to vessel,

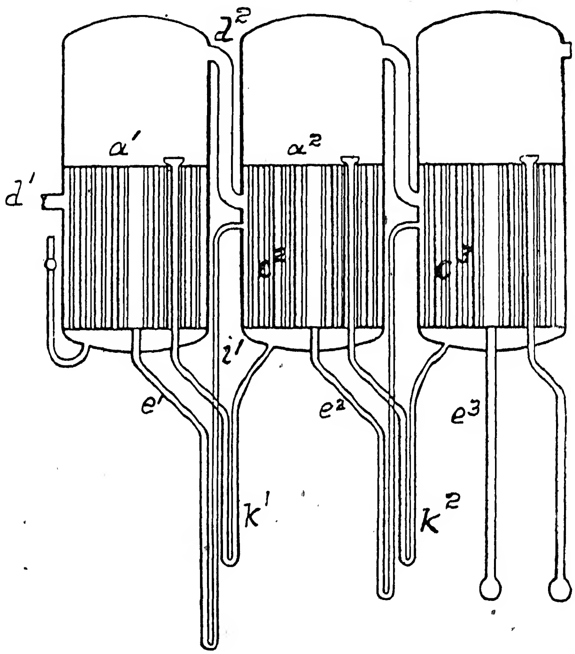


FIG. 145.—Sectional diagram of the three vessels of a vertical triple effect fitted with syphonic connections for the passage of juice and condensed steam from vessel to vessel.

is provided without the intervention and regulation of numerous valves. Fig. 146 shows such a triple effect as it stands ready for work in the factory; and Fig. 145 is a diagram explaining the principles of its mode of working and construction.

Taking first into consideration the utilisation of the heat agent, it will be perceived that the initial steam enters the

calandria of the first body of the apparatus through the inlet d^1, where it is condensed. The water due to this condensation is not at once removed from the apparatus, although it promptly leaves this particular calandria without hanging about within it, and thus hampering the

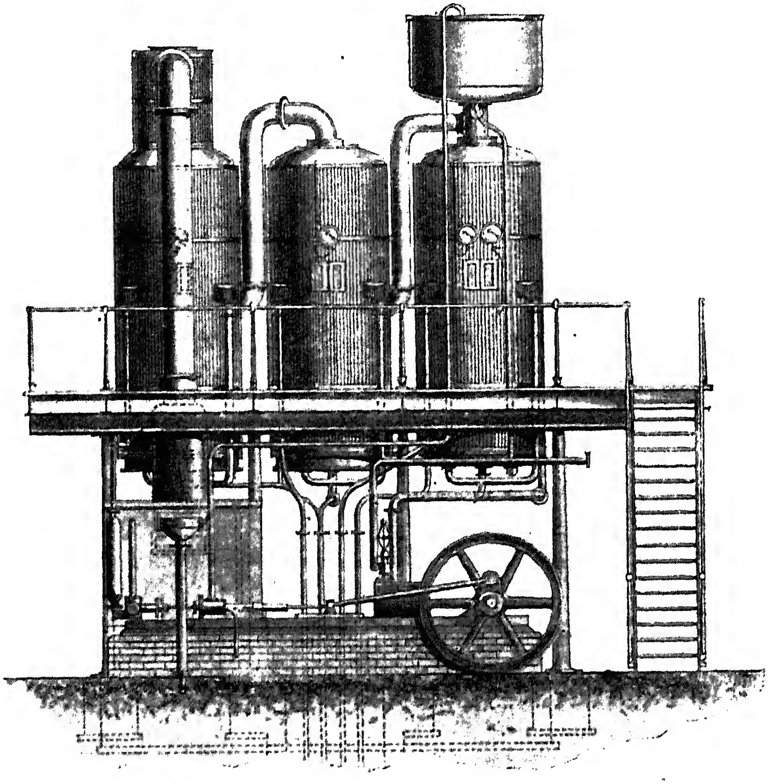


FIG. 146.—Exterior elevation of a triple effect fitted with the syphonic connections seen in Fig. 145.

full action of the steam. It has a quite free exit by the down-pipe e^1, which forms one of the legs of an inverted syphon. Having fallen down the latter to a depth of some 25 feet, it rises again through the second leg i^1, and enters the second calandria at a convenient height above the lower

tube plate, the water thus discharged into the second drum parting with its excess heat, and thus supplementing the work done by the vapour which is also being introduced into this same calandria from the juice space a^1 of the first body via the connection d^2. By these means the condensation water has a free and regular exit from calandria to calandria, and is thus utilised for further useful effect instead of being withdrawn from the apparatus. It is claimed besides that this utilisation is effected, through the intervention of the syphon, without impairing the proper conditions which should obtain in the second calandria c^2. Similarly the condensed vapour, together with the introduced and cooled water, is freely passed from the second calandria, via the second syphon e^2, to the third calandria c^3, where it joins the cooler vapour which also enters from the second vessel a^2. Having yielded up their available heat, and performed the duty of that share of the evaporation which is effected in this last vessel of the effect, they are conjointly and finally removed from the apparatus, as warm water, via the pipe e^3, either through the agency of a suitable calandria pump, or by being led through a pipe to the main condenser of the effect. It is obvious that this procedure increases the heat efficiency of the evaporator as an integral machine, and is productive of a corresponding increase in the amount of work done by the initial supply of steam.

Taking next the passing of the juice from vessel to vessel, it is seen that this is effected by similar syphons, k^1 and k^2, which, through their intervention and by virtue of the natural laws which regulate their action, dispense with the majority of the customary regulating valves, while one juice admission valve controls the passage oft he liquids throughout the entire apparatus. Various conveniences, not shown in the illustration, are offered for the purpose of

promoting as good a circulation of the juice as possible, while the latter remains in each vessel, and it should be noted that the outgoing juice is collected for withdrawal in the syphon head cups which are located immediately above the upper surfaces of the respective calandrias.

Fig. 147 gives particulars of yet another bulk evaporator, of which the special features are the characteristic methods employed to effect a very thorough distribution of the steam and vapour amongst the whole of the tube surfaces of each calandria. Special attention is, moreover, paid to

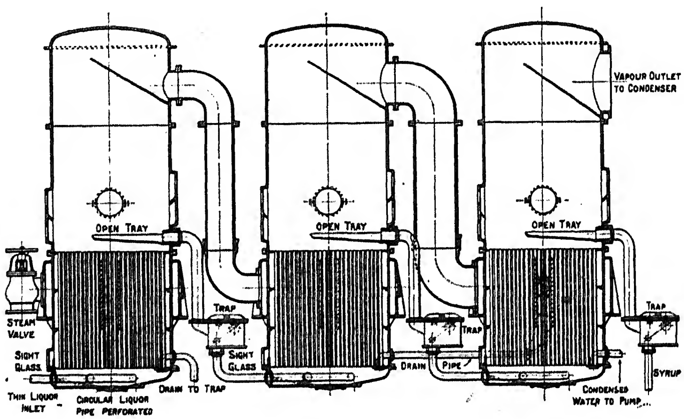


FIG. 147.—Sectional elevation of another form of triple effect.

the automatic regulation of the flow of liquor between consecutive vessels, which is controlled by specially designed traps. It will also be seen that proper care has been devoted to the respective sizes of the vapour pipes connecting the three vessels of the complete effect. The effective distribution of the steam or vapour amongst the tubes is promoted by horizontal and vertical baffle-plates fixed within the calandrias. The horizontal baffles are intended to ensure the action of the hottest steam upon the upper portion of the tube surfaces, the tube holes in the

baffles being larger than the tubes which stand in them, so that the annular spaces thus formed serve as steam distributors, leading to the lower sections of the calandria. It will be noticed that there are no special circulating tubes in these calandrias, and the vertical baffles are intended to establish definite up and down currents, those tubes to the left of them accommodating the upward, those to the right the downward circulation. By these means a lesser diameter of calandria is required for a given amount of heating-surface with any given length of tubes, and the diameters of the bodies of the apparatus are correspondingly smaller, so that the floor space occupied by triple effects of this design is less than in some of the evaporators already described, and the first cost of the complete apparatus is kept down to a correspondingly lower figure. An automatic regulation of the passage of the juice from vessel to vessel is obtained by the employment of specially designed open trays and juice traps, which act as substitutes for the syphons in Fig. 145, permitting the transmission of the juice without the accompaniment of any of the uncondensed vapour which should properly pass in another direction through the large vapour pipe on its way to the succeeding calandria. Various minor yet characteristic details are seen in the sectional view of this effect.

Another bulk evaporator which presents points of great interest is shown in Figs. 148 and 149. The upper portions of the bodies of this effect are marked by the same simplicity of style seen in the previous illustration, and various accessories, together with all the details of the columns and staging provided for their support, are well defined. A careful examination of these illustrations will reveal what is the leading characteristic of this apparatus, which is somewhat hidden away beneath the staging in the one view and partially obscured by the shadow of the

platform. The sectional illustration, however, shows that the calandrias and lower portions of each vessel are canted to one side; that is to say, the vertical centre lines of the triple effect bodies and their respective calandrias form an obtuse angle with one another. In each of the vertical

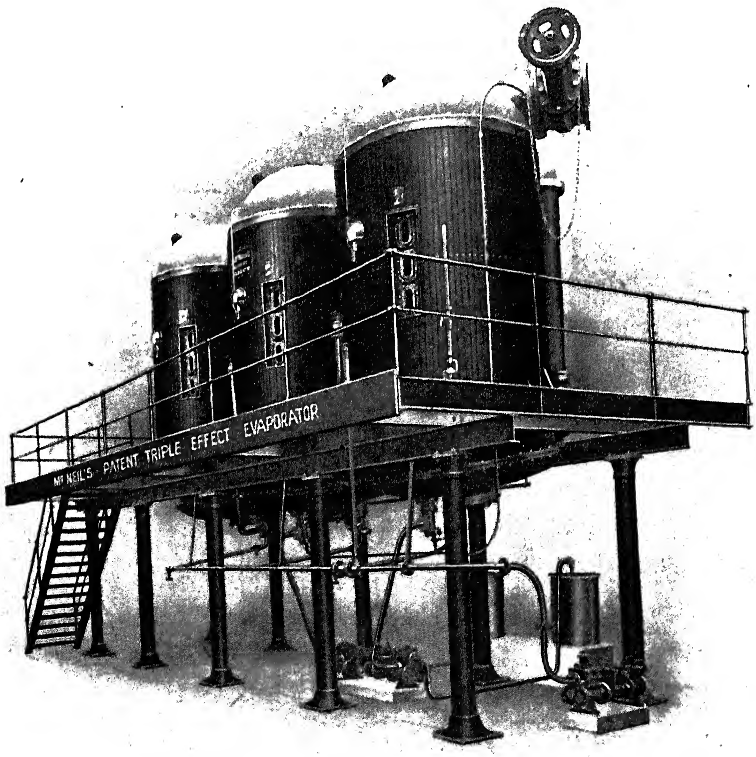


FIG. 148.—Elevation of triple effect fitted with inclined calandrias.

multiple-effect evaporators previously described, the heating tubes have themselves been placed in perfectly vertical positions, but in the present case they are inclined to one side, and lie somewhat towards a horizontal position, and these vertical vessels are thus associated with inclined

calandrias. It should also be particularly noticed that the steam and vapour are admitted at the higher side of the latter. A double purpose is achieved by this arrangement, in connection with the circulation of the juice in contact with one side of the heating surface, on the one hand, and the action of the steam or vapour impinging upon the outer side, on the other. It is obvious that, by virtue of this arrangement, an upward current of circulating juice is maintained in those tubes which are located in the more

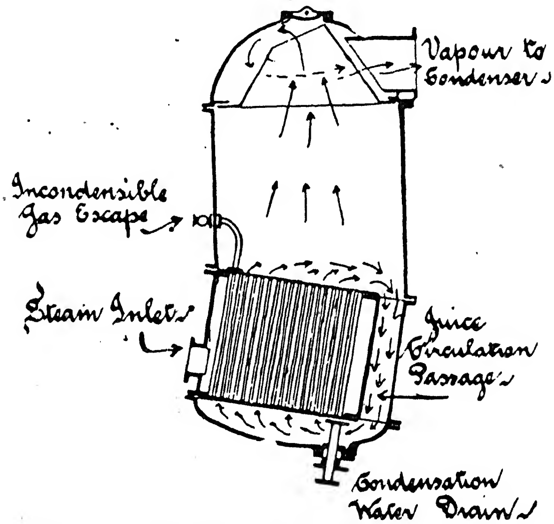


FIG. 149.—Section of a triple-effect vessel fitted with an inclined calandria.

elevated portions of each calandria, and such juice, upon issuing from the upper orifices of these tubes, is directed along the upper sloping surfaces of the tube-plates, to be ultimately led by the circulating tubes in the lower regions of the calandrias to the lowest portions of the juice spaces of the vessels. In this way an excellent juice circulation is ensured. With reference to the action of the steam upon the outside of the tubes, it has first to be observed that much stress has already been laid upon the great importance

of promptly removing all condensation water from the interiors of the calandrias; and the great amount of care and attention which has been bestowed upon this detail and the various methods that have been instituted with regard to it have been frequently described. But while similar arrangements are retained and employed in conjunction with these inclined calandrias, the angle at which their tubes are placed is intended to procure still further advantages. It is an established fact that sluggish films of water and juice adhering to the surfaces of the tubes tend seriously to retard the transmission of heat; and in the case of perfectly vertical tubes there is a stronger tendency for such films to hang about throughout the entire length, and on all sides, of tubes so placed. In the case, however, of the inclined tubes this tendency is said to be diminished, and a corresponding increase in the efficiency of the heating surface is promoted. Moreover, the lower sloping tube-plate more readily leads the condensation water to the point where the outlet to the trap and pump is situated.

Earlier in this chapter an attempt was made to explain the preference which gradually asserted itself in favour of film evaporation in connection with the use of the earlier forms of steam evaporators worked under atmospheric pressure in conjunction with correspondingly high temperatures, and some of the reasons for such preference were given. As with these high-temperature evaporators, so also with vacuum apparatus, a similar appreciation of film evaporation has gradually manifested itself. It is indeed very significant that, with an increased velocity of juice circulation within the confines of the latter, or by the establishment of a more or less approximate condition of juice films within bulk evaporators by means of various devices, the efficiency of bulk evaporators has always shown a tendency towards the attainment of improved

results so far as the amount of work performed by a given amount of heating surface is concerned. Before entering, therefore, upon any description of film evaporators, it will be opportune first to notice important accessories which

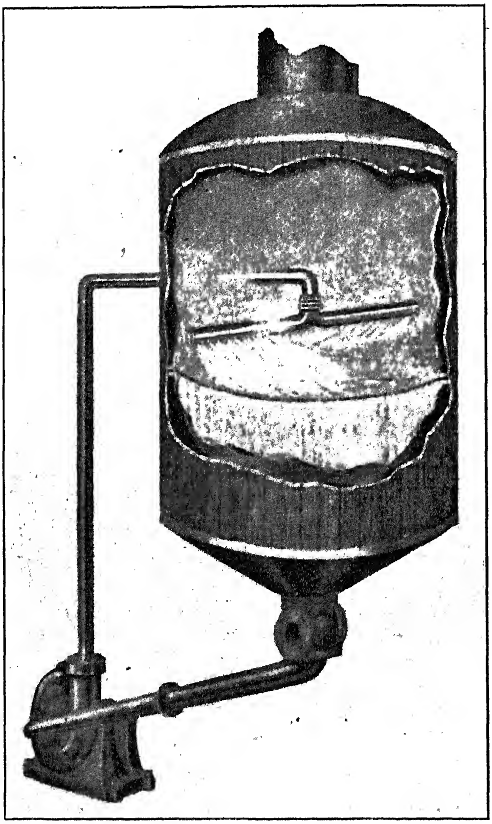


FIG. 150.—Apparatus for effecting the film distribution of the juice over the heating surfaces of a triple effect.

have been, and can always be, applied to most of the above triple effects which have for their object the establishment of as approximate a condition of film evaporation as possible in conjunction with the use of multiple effects that have been originally designed for the purposes of evapora-

tion in bulk. Fig. 150 explains the general intention of these ingenious accessories, which promote circulation of the juice under treatment, combined with a film distribution of it over all portions of the calandria tube surfaces. As will be seen, these devices deliver the incoming juice in the form of spray or in drops rather than in bulk, so that it is distributed over the heating surface as a film which readily becomes heated. In the case of this particular illustration, the spraying pipe is rotated by means of the

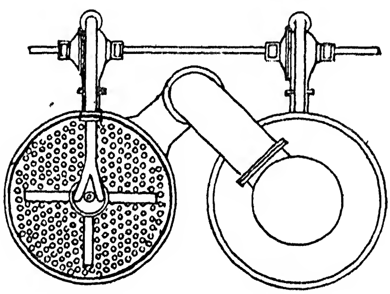


FIG. 151.—Plan of multiple effect fitted with juice-film distributor.

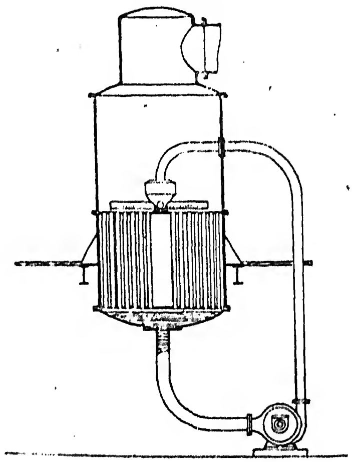


FIG. 152.—Section of multiple effect fitted with juice-film distributor.

incoming liquor through the reaction of the latter, and a continuous film of the same streams down the inner surfaces of the tubes. Upon falling out of the lower orifices of the revolving arms, the juice, after passing through the tubes, is collected in the bottom of the vessel, but is not allowed to accumulate, being immediately conveyed to a circulating pump located on the floor beneath the effect, which repasses it upwards to the spraying pipe for re-treatment or for removal to the succeeding vessel.

The other form of distributor consists of revolving

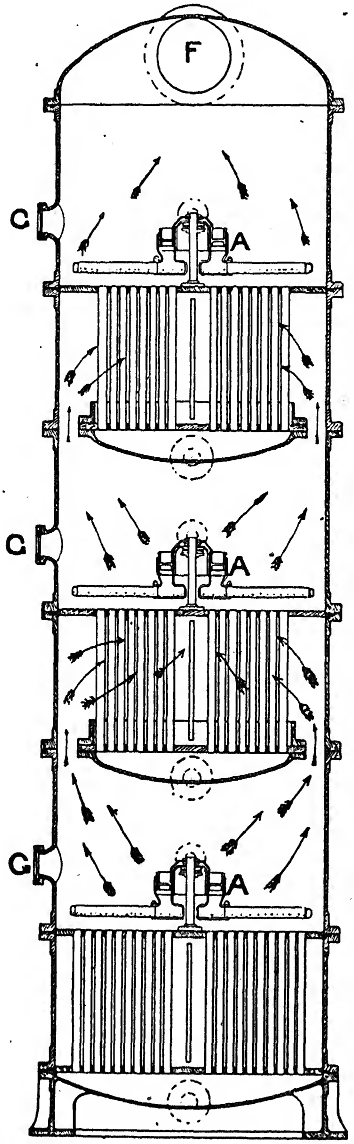


Fig. 153.—Section of superimposed multiple effect shown in Fig. 155.

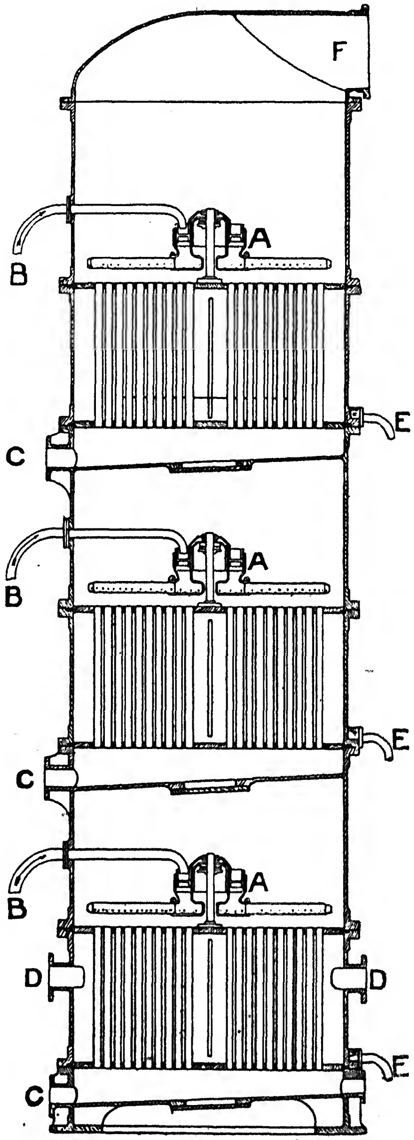


Fig. 154.—Another section of superimposed multiple effect taken at right angles to that shown in Fig. 153.

perforated arms actuated by a motor worked by the juice from the discharge pipe of the circulating pump. Figs. 151 and 152 show respectively a plan and section, from which it is seen that the juice impinges on the vanes of the motor, causing the arms to revolve. It then flows into the distributing arms and, passing out of the perforations in them, falls on to the heating tubes of the calandria in the form of a finely divided spray. It will be noticed that these perforations are provided on both sides of the arms, and it is claimed that the surfaces of the tubes of the calandria are thereby subjected to more complete washing than when the juice emerges from one side of the revolving arm only. The facts that the bearings are not in contact with the juice, and that no back strain is thrown on the pump, are also quoted in favour of this form of distributor.

The facility which distributors of this nature afford for constructing film evaporators on the lines of bulk apparatus is well exemplified by the evaporator given in Figs. 153, 154, and 155. This evaporator is remarkable as having the vessels superimposed, the first vessel being at the bottom of the structure. In this way outside vapour connections are done away with. Figs. 153 and 154 show vertical sections at right angles, from which it is seen that the vapour passes freely from the lower vessel to the heating surface of the one above through the calandria peripheral spaces. The advantages of this arrangement are that vapour friction is reduced to a minimum, while by the simultaneous distribution of the vapour over the entire heating surface a maximum efficiency is obtained.

The juice from the circulating pump attached to each vessel is discharged on to the motor A of the distributory arms, causing the latter to rotate as mentioned above. The juice, after streaming down the sides of the calandria tubes, collects in the juice space below, whence it is carried

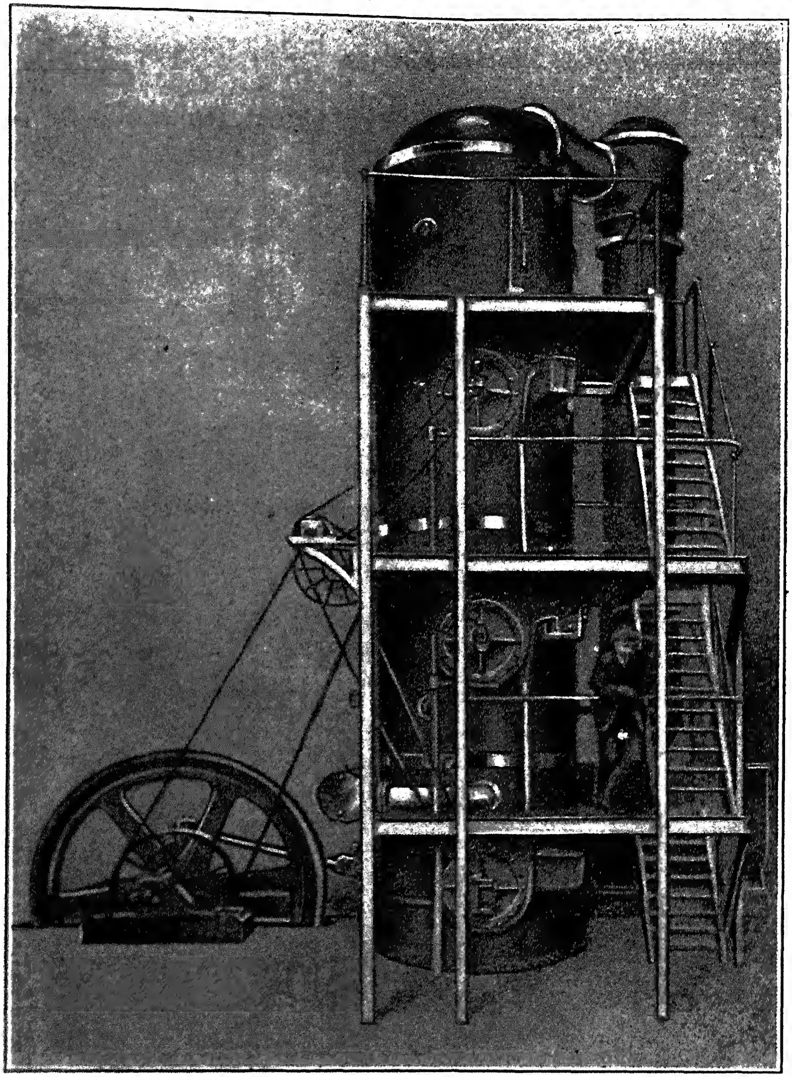


FIG. 155.—Exterior view of superimposed multiple effect shown on p. 264.

through C by the circulating pump to the distributor again. The condensed water is drawn from the calandria by pumps, a ledge attached to the edge of the lower tube-plate, where it is cut away to form the vapour orifice, preventing its

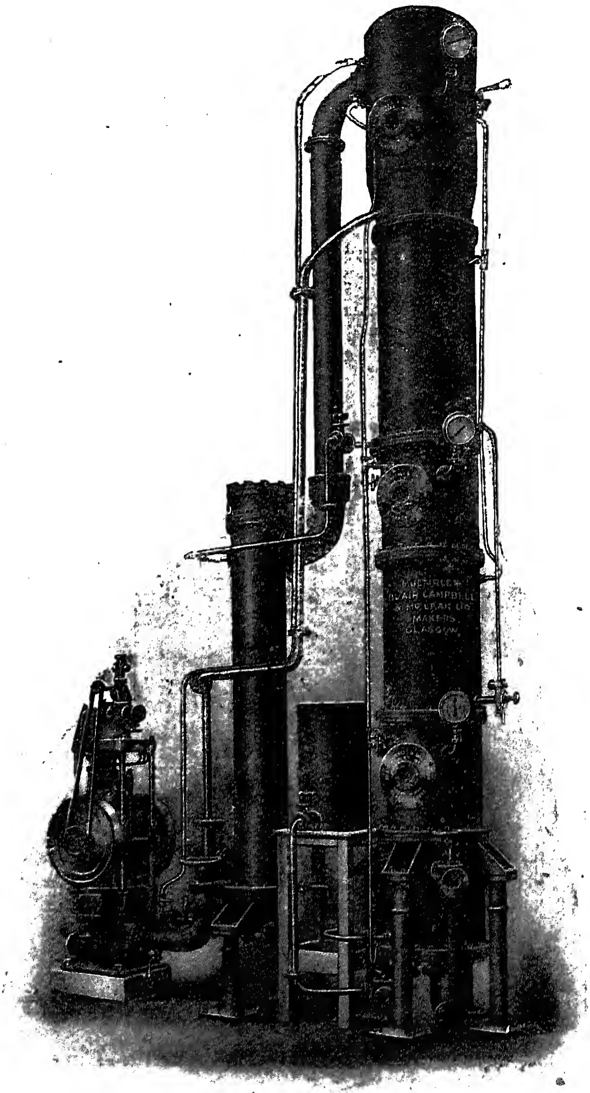


FIG. 155A.—General elevation of patent vertical evaporator.

return to the vessel below. In Fig. 153 a section is given in which the lower tube-plate vapour orifices are shown.

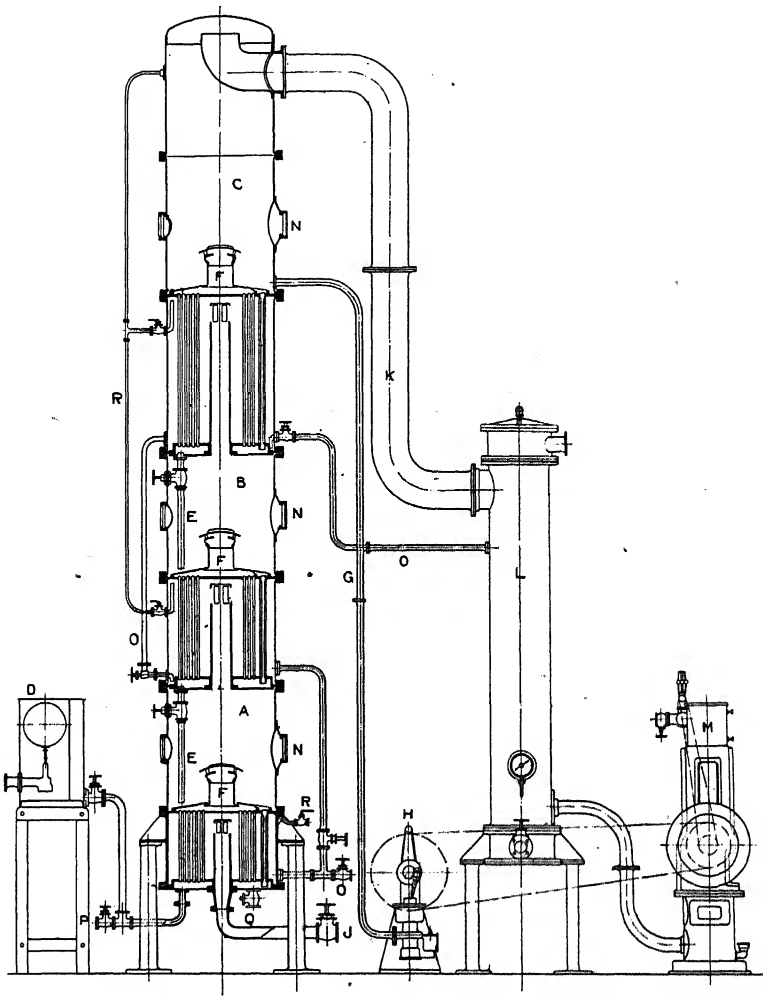


Fig. 155b.—Section through patent multiplex vertical film evaporator.

A, 1st effect; B, 2nd effect; C, 3rd effect; D, automatic liquor control tank; E, liquor pipes between effects; F, liquor separator; G, concentrated liquor discharge pipe; H, concentrated liquor extraction pump; J, steam inlet; K, vapour pipe to condenser; L, surface condenser; M, vacuum pump; N, manhole and sight glass; O, condensed water-pipes; P, wash water connection; Q, drain value; R, air drains.

As with the vapour from the boiling juice, steam is admitted to both sides of the first vessel.

This form of evaporator occupies but little space, is of great simplicity of design, and lends itself especially to the

FIG. 155C.—Showing the facilities provided for the cleaning of the effect shown in Fig. 155B, access to the removable covers being obtained through the manhole doors N, as marked in that Fig.

Torricellian form of condensation. Great efficiency of heating surface is also claimed for it, while the cost of construction and erection is exceptionally low. Equilibrium

valves regulate the transference of juice from one vessel to the other, rendering the working of the evaporator automatic, so far as the juice supply is concerned. This evaporator combines the simplicity of construction of a bulk with the high duty of a film evaporator.

Figs. 155A and 155B give details of a further apparatus of this class of evaporator of recent design. Fig. 155B is a section of a triple-effect constructed on these principles, the details of which are explained in the accompanying list.

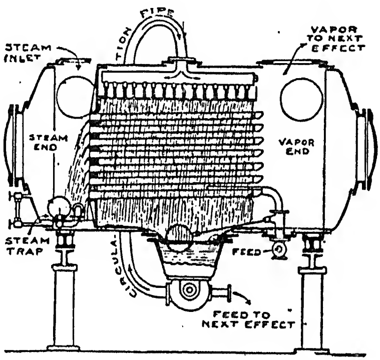


FIG. 156.—Section of one vessel of a horizontal multiple-effect film evaporator.

Figs. 156 and 157 give particulars of another form of evaporator which combines the advantages of film evaporation in connection with horizontal vessels and horizontally placed heating surfaces. In this case the circulation of the juice is maintained by the employment of circulating pumps, in a manner very similar to that just described, the distribution of the fluids being, however, effected by fixed troughs with perforated bottoms, which are located above the horizontal tubes of the calandrias, the juice flowing out of the troughs on to the exterior surfaces of the tubes, while the steam acts from within them. The tubes themselves are fixed in "staggered" vertical rows, so as to

prevent the escape of untreated juice, and to ensure as perfect a film as possible over the exterior surface of all the

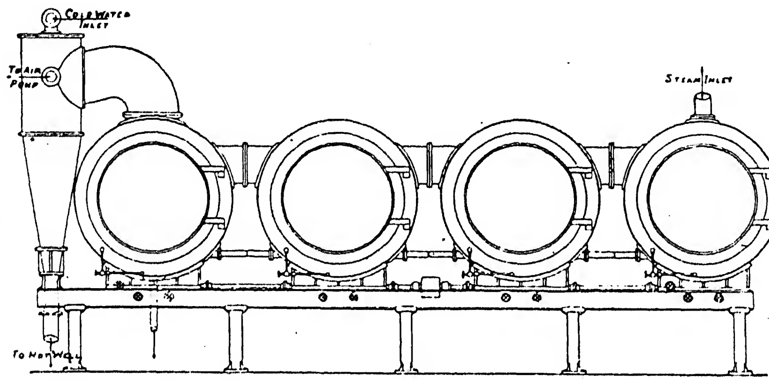


FIG. 157.—Front elevation of a quadruple-effect horizontal film evaporator as seen in section in Fig. No. 156.

tubes. Their " vapour ends " are virtually closed, a very small hole permitting the desirable escape of uncondensable

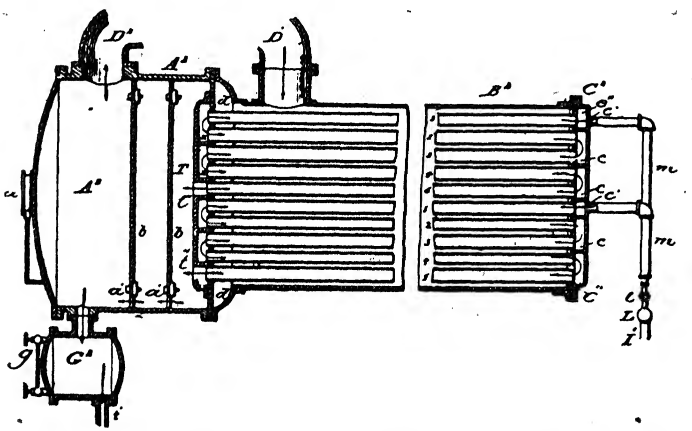


FIG. 158.—Section of one vessel of another horizontal film evaporator.

gases, and the condensation water flows back into the " steam end " of each vessel, as seen in Fig. 156, and it is usually drawn thence through a trap into the " steam end "

of the next coolest body. This illustration also shows the circulation of the juice under treatment as a heavy shower, the latter, as already indicated, being steadily maintained

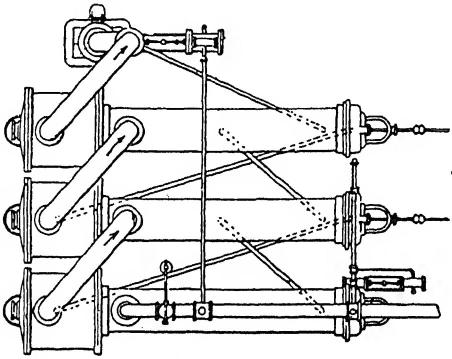


FIG. 159.—Plan of triple-effect horizontal film evaporator, as seen in section in Fig. No. 158.

by the circulating pump attached to each vessel. The circulation is thus independent of temperature, and there is no mass of juice through which the generated vapours

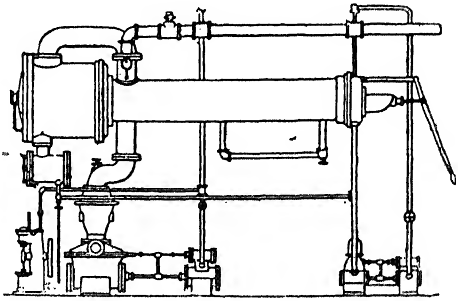


FIG. 160.—Side elevation of triple-effect film evaporator, as seen in plan in Fig. 159.

have to force their escape. In all classes of film evaporators this feature enables them to be worked efficiently at smaller differences of temperature than are necessary in the case of bulk evaporators. It is claimed that the apparatus now described offers special facilities for cleaning both

the inner and outer surfaces of the calandria tubes, inasmuch as the inner surfaces are accessible from the "steam end" of each vessel, while the outer surfaces can be reached from their "vapour end," thus ensuring the important condition of the continuous cleanliness of all portions of the heating surface throughout long periods of service. Fig. 157 shows this apparatus as it would be arranged for a quadruple effect. Sometimes such an apparatus is arranged to work in reverse directions, reversing vapours as well as juice, in which case a second condenser is placed to the right of the effect as well as to the left, and the extreme vessels then can act alternatively as the first or the last vessel of the effect as desired. Such reversal materially assists the cleansing of the heating surfaces from scale, the latter being cracked off the outside of the tubes by the action of the different degrees of expansion to which both scale and tubes are thus subjected.

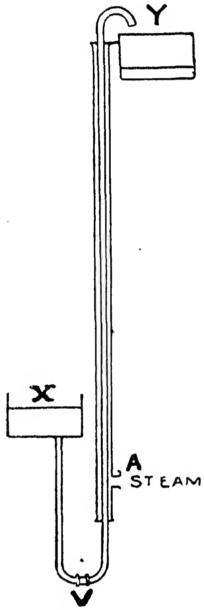


FIG. 161.—Sketch illustrating principle of the "climbing-film."

Figs. 158, 159, and 160 give particulars of another horizontal film evaporator which has been largely used in sugar factories, and is still employed in connection with various industries, more especially where the distillation of salt water and other compound fluids is concerned.

There is a characteristic difference in this apparatus to the effect shown in Fig. 156, inasmuch as the juice flows, in its case, through the tubes, while the steam or vapour surrounds the exterior surfaces. Fig. 158 explains the

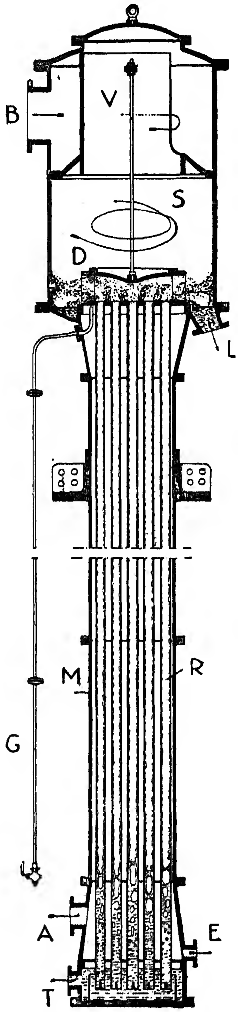


FIG. 161A.—Section of patent "climbing-film" evaporator.

A, Live steam inlet; B, vapour outlet; D, centrifugal baffle; E, condensed water outlet; G, air drain; L, concentrated liquor outlet; M, calandria; R, evaporating tubes; S, separator; T, weak liquor inlet; V, save-all.

manner and details of its working arrangements, and it will be seen that the steam or vapour enters each vessel through the upper connection D^1, thus surrounding the tubes and permeating the interior of these sections of the effect. The juice enters the section C^2, and its passage through the tubes is indicated by the arrows, which show that a certain number of these tubes are "nested" so as to form a "coil" of suitable length, through which the juice flows successively in alternate directions, thus affording a sufficient opportunity for the steam to act upon it. The treated juice leaves each vessel via the separator A^2 and the trap G^2, on the way to the next section of the effect, while the vapour proceeds to the succeeding calandria via the outlet D^2.

Fig. 159 is a plan of this effect showing the relative positions of the various vessels and their respective connections, while Fig. 160 is a side elevation of the same apparatus.

A point of very considerable interest in connection with the foregoing evaporator is that its employment has led to the invention of a novel apparatus now about to be described, which is shown in Figs. 161, 161A, 162, 163, and 163A.

The object is to secure a more uniform film of juicc over the entire tube surfaces than was obtainable by the employment of the horizontal effect just described, and it is claimed that this has been effected by the use of some-

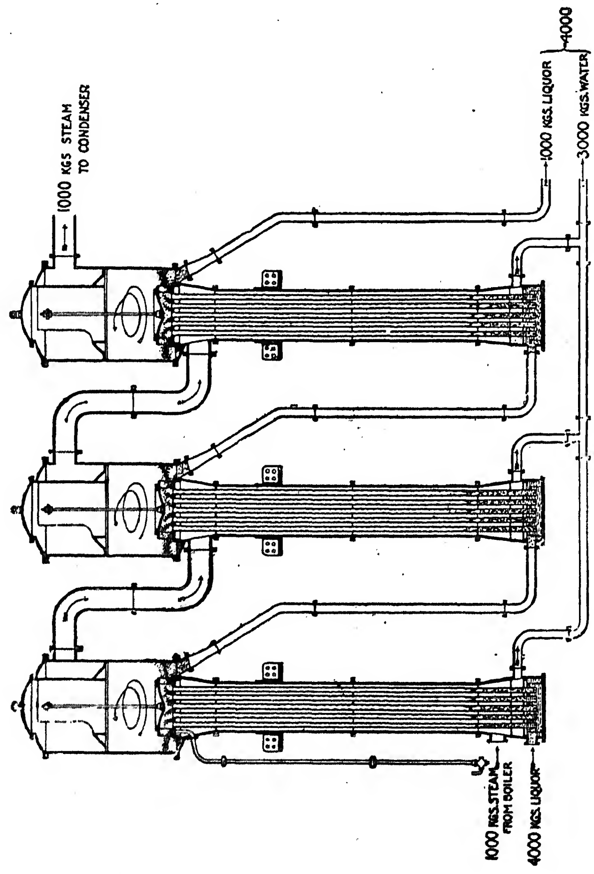


Fig. 162.—Side sectional elevation of a vertical triple-effect "climbing-film" evaporator.

what similar vessels and calandrias placed in vertical positions. Broadly, it may be said that the latter is a vertical and simplified edition of its predecessor. The principle on which a perfect film is formed over the entire tube surface is best explained by a reference to Fig. 161, in which X represents the tank containing the weak juice which is

delivered into the base of the evaporator through the valve V. The heating agent enters each vessel of the effect via the inlet A, and surrounds the outside surfaces of the tubes, while the liquor passes upwards through the tubes. The juice may enter the evaporator, as

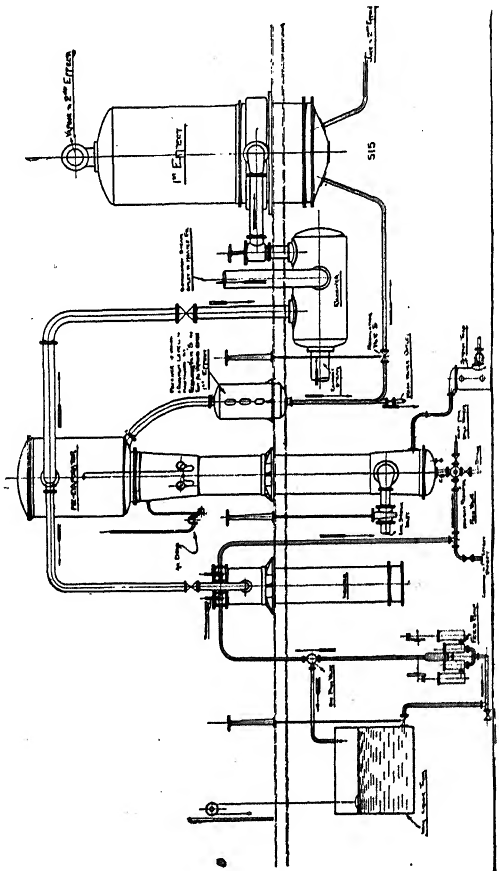


FIG. 163.—Diagram of a "climbing-film" evaporator, working as a single-effect pre-evaporator, in conjunction with a standard vertical-effect.

above, under a small head of some 3 feet, and, as boiling takes place, a climbing action ensues, the steam generated filling the centre of the tube, while the liquor climbs on the inner surface of the latter in a thin film. The fact of this behaviour is said to be demonstrated

by the following experiment. When the evaporator is working, a dark-coloured liquor is injected through the valve V, and it is found that one or two minutes elapse before a trace of colour appears at the top of the vessel,

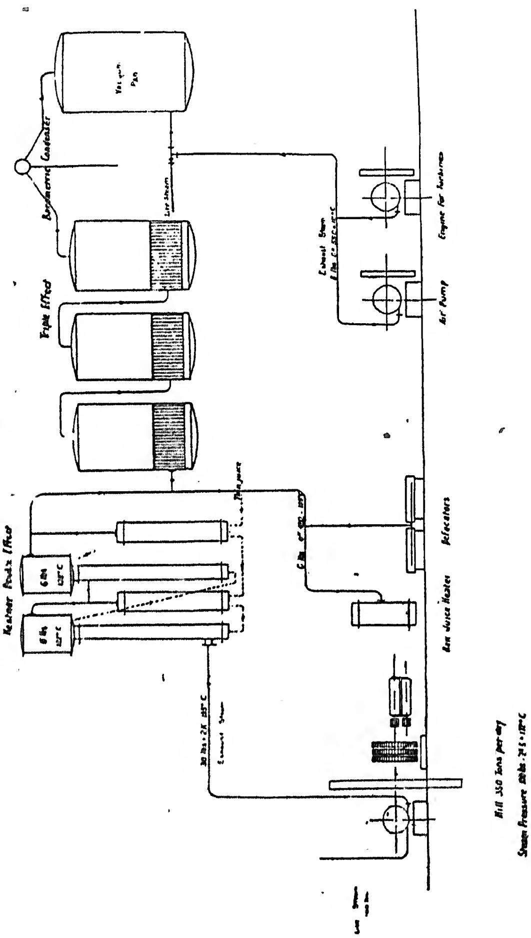


FIG. 163A.—Diagram of a "climbing-film" evaporator, working as a double-effect pre-evaporator, in conjunction with a standard vertical triple-effect.

although the generated vapour is exhausting at a speed of about 60 feet per second. If there were the smallest particle of liquid in the middle of the tubes, it would be discharged by the vapour, and the dark colour would instantly show

itself in the top separator of the vessel. It should be borne in mind that the juice is not pumped up through the tubes of the effect, but that it climbs up the inner surfaces, while the central area remains free for the passage of the expelled vapour. Moreover, the liquid passes only once through the tubes, and then goes on to the following vessel, where the same process is repeated. In connection with the above phenomenon of "climbing," which is apparently caused by the rushing vapour, no undue importance is to be attached to the question of the level or head of the juice-feed, for the latter may be effected in the usual way from a pump or elevated tank under the control of a regulating valve, which can be adjusted to admit the proper amount of juice required for the proper working of the apparatus.

Fig. 161A explains how these principles and requirements are met in the design and construction of a "climbing-film" multiple effect, which, so far as its general working is concerned, is subject to the same laws and details of operation as have been emphasised in connection with all forms of multiple-effect evaporators. The standard length of the 3-inch vertical heating and circulating tubes is usually about 23 feet, and Fig. 162 shows how a multiple effect, comprising three such vessels, is arranged in the construction of a triple effect. The total height is considerable, and this feature renders it peculiarly suitable for use in connection with a Torricellian Condenser. As will be noted in the illustrations, a centrifugal separator, with save-all, is provided at the head of each vessel, and the vapour and climbing juice striking the former, a separation of vapour and juice is effected. Figs. 163 and 163A show such vessels working as pre-evaporators, both by single and double effect, in conjunction with a standard vertical triple effect.

CHAPTER VIII

CRYSTALLISATION

THE juice has now been concentrated to varying points, adapted respectively to whichever process of crystallisation is to be employed. These may vary from a density of 40° Bé. with the muscovado process, the point at which the juice leaves the copper wall, or steam pan, in a state of supersaturation, to the lower figure of 17° to 18° Bé. when open concentration in conjunction with the vacuum pan is employed. The usual density of the syrup, however, when it comes from multiple-effect evaporators is 30° Bé., corresponding to a water content of about 45 per cent.

In the muscovado process the next step is to start crystallisation by cooling the highly heated syrup. This, with the ordinary process, is done by transferring it from the last vessel of the copper wall, or from the Aspinall, Wetzel, or Bour pans, or other apparatus by which the finishing stages of concentration have been carried out, to flat rectangular tanks. The temperature is high, somewhere about 230° Fahr., and it is this high temperature which has had the effect of preventing the crystallisation of the cane sugar during the boiling process. As the temperature falls, granulation takes place, and the cooling mass rapidly becomes a magma of fine crystals mixed with mother liquor—the molasses. A crust first appears on the cooling surface, and has to be broken as it forms, to secure uniform cooling throughout. At the end of two or three days the crystallisation is usually complete.

A process whereby the cooling operation is accelerated, while at the same time the motion involved develops a larger grain in the sugar, is that of oscillation. An oscillator is shown in Fig. 164, an apparatus which, in a somewhat primitive form, has been in vogue for many years. It will be seen that it consists of a semi-cylindrical tank, which holds the highly concentrated syrup to be operated upon.

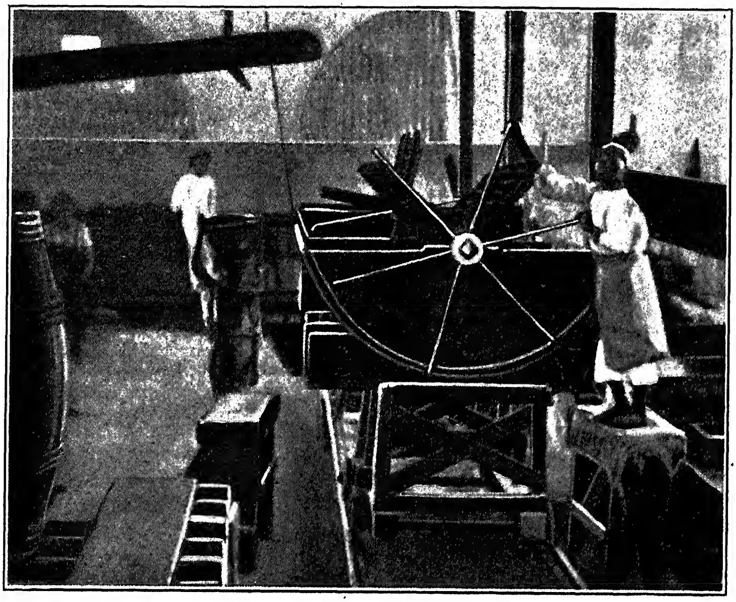


Fig. 164.—"Oscillator" at work in a common-process sugar factory.

A shaft extends from end to end of this receptacle, upon which are mounted four wooden frames or arms. These, as seen in the illustration, are so constructed that when they slowly revolve they effectually disturb the gradually solidifying mass contained in the tank. The result of this operation is to start a crystallisation, partly by the cooling and partly by the effect of the stirring on the concentrated syrups. Further crystallisation in the coolers takes place,

mainly by deposition on the crystals already formed, thus securing a sugar of better grain than when oscillators are not used. As, however, has been already mentioned, but little sugar is now made by the muscovado process, and that only under exceptional conditions. What is made, however, if of good colour and grain, commands a ready market; partly by reason of its rarity, and partly on account of its rich flavour.

The vacuum pan, in which, outside of India, probably 99 per cent. of the cane sugars of the world is made, was, as already mentioned, invented in 1812. It was not, however, until the introduction of the centrifugal that this appliance came into use in cane-sugar manufacture, on account of the difficulty which was experienced in separating the molasses from the crystals. Fig. 165 gives a vertical section of a modern standard vacuum pan of the coil type, which embodies the results of many years' experience and careful study of the requirements of sugar-boiling, and is especially suitable for the concentration of cane juice to the highest density admissible, coupled with the formation of sugar crystals. A comparison of this illustration with the early form of vacuum pan, shown in Fig. 126, will indicate the development of this apparatus during the intervening period. Very particular attention is paid to the disposition of the heating coils, and the amount of heating surface in the latter is kept as large as possible. These coils are generally made of solid-drawn copper, and are usually about 4 inches diameter. Bearing in mind the fact that during the progress of concentration they are up-borne and shaken by the boiling contents of the pan at a specific gravity of nearly one and a half times the weight of water, and that during the operation of emptying the pan they are borne downwards by the same viscid mass which surrounds them, it will be realised that it is necessary that they should be well supported in either direction by the strong bar-stays

shown, which, in conjunction with the use of suitable brass clips, securely hold the coils in position against both upward and downward strains. The particular shape of the cylindrical shell of the pan itself is a matter of much interest. It has been settled by experience, and it is important to

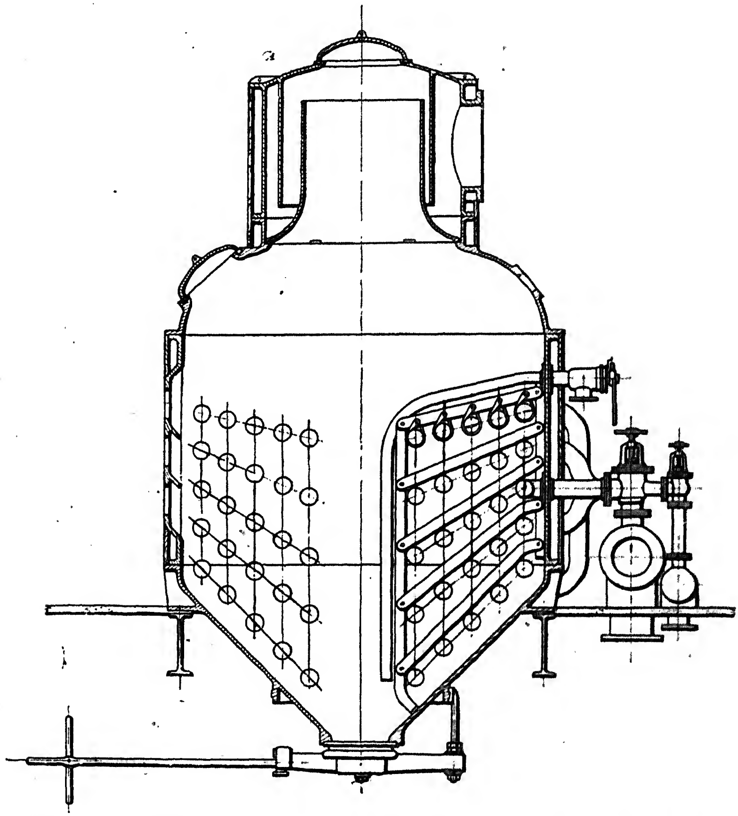


FIG. 165.—Vertical section of a standard vacuum pan of the coil type.

note, that all modern pans have very deep conical bottoms, which provide for a rapid and complete discharge of their contents when the pan "strikes." To the same end the discharge valve is proportionably large, having brass faces and rubber joint-rings which act as a safeguard against air

leakages whilst the pan is at work. The body of the pan is usually surmounted by a dome-shaped terminal cover, as well as by a "save-all" of somewhat more or less elaborate design, which culminates in a large vapour outlet, with branch, the latter joining up to a capacious vapour pipe which ultimately leads to the condenser and vacuum pump. The "save-all" or entrainment preventer is specially arranged with the object of preventing the sugar from being carried away to waste along with the vapour.

This question of entrainment has been specifically noticed in connection with the subject of multiple effects (Chapter VII.), and it has been suggested that in their case its avoidance could be largely ensured by maintaining carefully regulated low levels of the juice boiling in them. This particular method of safeguarding against waste of sugar is not, however, available in the work of the vacuum pan, and it is absolutely necessary to meet the evil in the latter case by the use of the special preventives shown in the various illustrations and more particularly referred to in a later portion of this chapter, or, preferably, by the adoption of the more revolutionary and effective method, that is steadily influencing the construction of multiple effects, of increasing the height between the highest point of the heating-surface and the lowest point of the vapour outlet. This method is particularly effective, and has likewise a most beneficial effect upon the general efficiency and evaporative power of the vacuum pan. In such cases the height of the "belt" of the pan may have to be increased fully 7 to 9 feet, preferably 10 feet, more or less according to circumstances, and the dome will thus be raised a corresponding amount above its customary position. The vacuum pan thus approximately assumes in appearance the outward semblance of a multiple-effect vessel, and the use of an anti-entrainment device is practically unnecessary.

Mechanical entrainment will not take place, and vesicular entrainment will be almost totally avoided.

Each pan is fitted with a charging-cock, steaming-out valve, and air or vacuum breaking tap; also with light and sight glasses, water cups, proof stick, thermometer and vacuum gauge. A steam-pressure gauge is likewise fitted to each coil of heating surface, as well as a steam trap, to keep the coils free from all condensed steam, and at the same time prevent the waste of the live steam itself. Particular attention has been paid to the point of making these heating coils as efficient as possible, both as to their disposition as well as to the certainty of keeping them filled with a full pressure of steam throughout their entire length. Excellent arrangements have been patented with a view to securing the fullest possible reduction of the number of steam admission valves, coupled with the advantage of enabling each complete circle of the coils to act simultaneously as a distinct unit so far as a full and proper supply of steam is concerned. These devices also specially provide for the immediate withdrawal of the condensed steam from each coil circle, thus ensuring the absence of any undue waterlogging of the latter.

Fig. 166 shows a vertical section of another style of vacuum pan, which, although practically similar in shape and general principles of construction to the pan just described, is chiefly characterised by the special form of the major portion of the heating surface employed in its case. It is termed a calandria vacuum pan, and it will be noticed that the maximum amount possible of the heating surface employed within it assumes the form of a calandria, the latter being very similar in its general features to the arrangements adopted in the case of the bulk multiple effects already described. The vertical tubes are short and of large diameter, expanded into brass or steel tube-

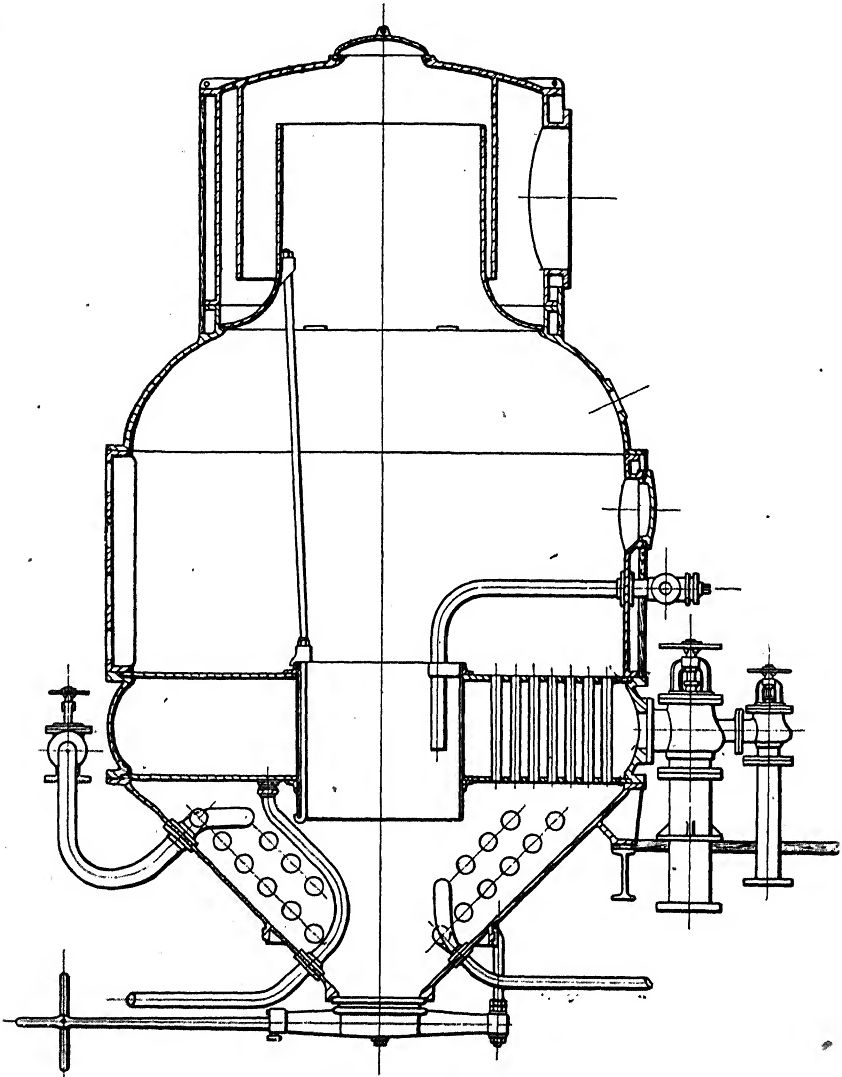


FIG. 166.—Sectional elevation of a calandria vacuum pan.

plates, and a large central circulating copper tube, extending towards the bottom of the pan, ensures a proper circulation of the boiling syrup. As the tube plates are

usually of large diameter they are frequently supported by strong tie-rods, which protect them from improper strains which would otherwise affect them, both when the pan is at work and is being emptied. The calandria is supplemented by additional coil-heating surface located in the cone-shaped lower portion of the vessel, thus preventing any stagnation of the juice circulation in the lower region of the cone. The illustration shows how the steam is admitted to the cone coils and to the calandria through the controlling stop-valves. It also demonstrates the manner in which the condensed steam, in the form of hot water, is led away from them.

With reference to all pan coil-sections, of whatever description, it is desirable to point out that in order to obtain the maximum output of massecuite in a minimum period, it is advantageous to arrange for the maximum portion of the heating surface to be brought into action as promptly as possible. That is to say, that as much as possible of the total and most effective heating surface should be placed in the lowest possible positions in the pan bottom. Sufficient attention is not always paid to this important point, and disappointment is experienced owing to the more limited output obtained in a given time than would otherwise result. In the case of calandria vacuum pans, modifications on the above lines have recently been introduced with good effect.

Turning from the consideration of the interior arrangements of vacuum pans, and consulting Fig. 167, it will be seen how the exterior of the vessel usually appears to an observer. In the example now presented, a very large apparatus is seen, capable of holding a "strike" of some sixty tons of massecuite, which, when "cured," will produce about forty tons of sugar crystals ready for the market. The various steam stop-valves which regulate the admission

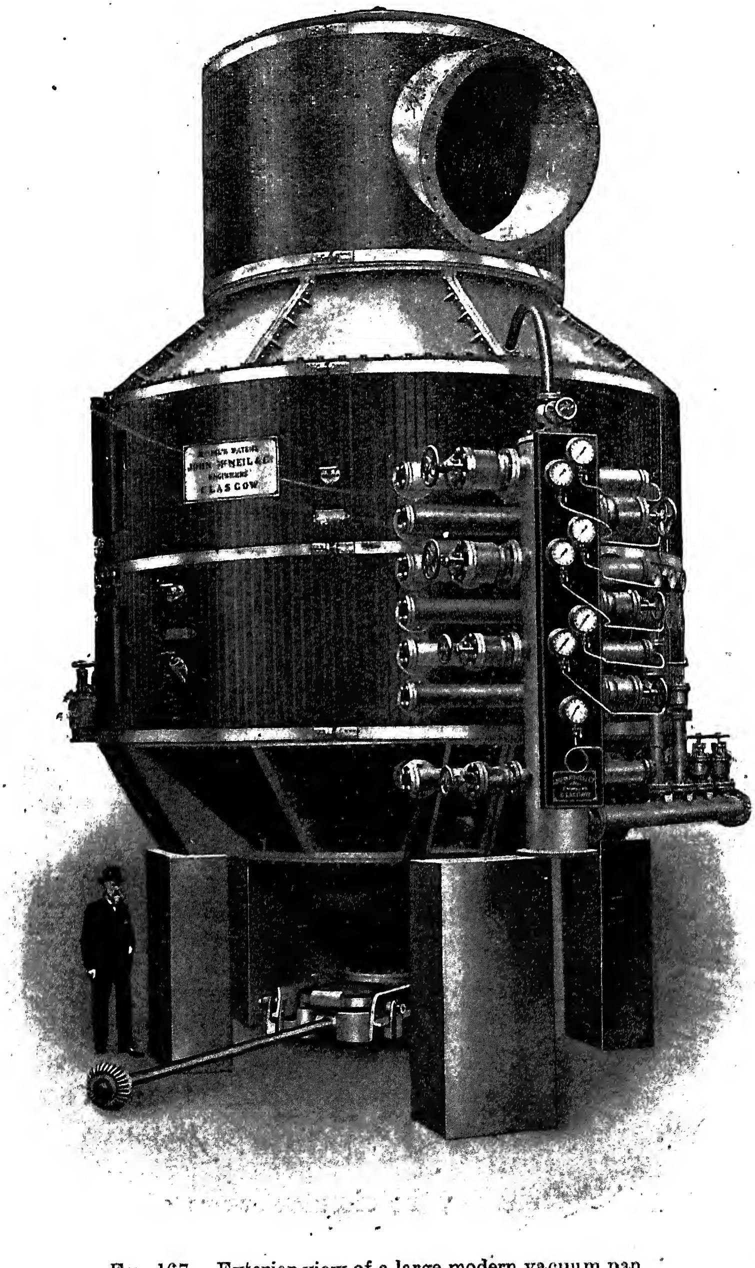


FIG. 167.—Exterior view of a large modern vacuum pan.

of steam to the different coils, together with their respective pressure gauges, are seen in position, as well as the proof sticks and the light and sight glasses. At the lower end of the bottom cone of the pan are the mechanism and general arrangements connected with the large discharge valve. Branching out from the cylindrical crown of the vessel is the large vapour outlet, which leads to the condenser and the vacuum pump. Within this capacious crown the anti-entrainment apparatus is fixed, which requires special notice, for, as already mentioned, loss by entrainment cannot, in the case of a vacuum pan, be avoided by any limitation of the height of the boiling contents, as in the case of bulk multiple-effect evaporators. Unless special precautions are taken, a considerable quantity of sugar may be lost in the form of particles of syrup carried over from the pan to the condenser along with the vapour. One effective method, and the most preferable of all, of preventing such loss, has already just been described. Another device is shown in Fig. 166, and a further arrangement is described in connection with Fig. 168. Within the dome of the pan a cone-shaped funnel is fixed, which collects and gives direction to the escaping vapour. The orifice of this funnel leads out obliquely towards the side of the dome farthest away from the outlet to the condenser. On issuing from the funnel the vapour, with whatever entrained syrup it carries, strikes on the roof of the dome, and, dividing into two streams within the annular passage between the funnel and the roof, sweeps round both to the right hand and to the left to the large outlet to the condenser, while the liquids projected on to the roof adhere to its surface, ultimately draining back into the body of the pan by gravitation. During the passage from the funnel outlet to the condenser, the circular sweep of the vapour around the cone leads to a further separation of any re-

tained syrup by centrifugal action. To prevent the syrup which is adhering to the roof of the dome being swept by the rush of vapour into the condenser, the large branch pipe leading to the latter is extended internally towards the funnel, as seen in the illustration; and this inward extension compels the vapour again to change its direction, thus still further dissociating itself from the liquid adhering to the dome. To provide for the return of the separated

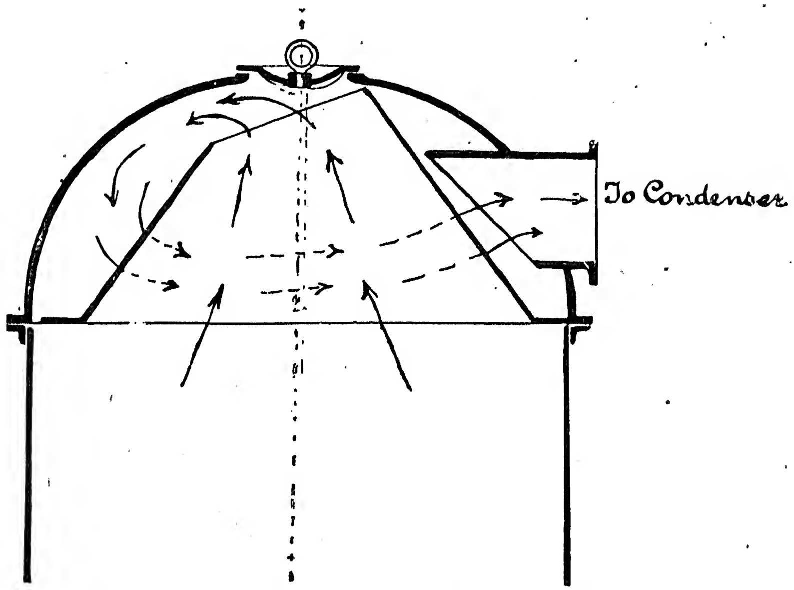
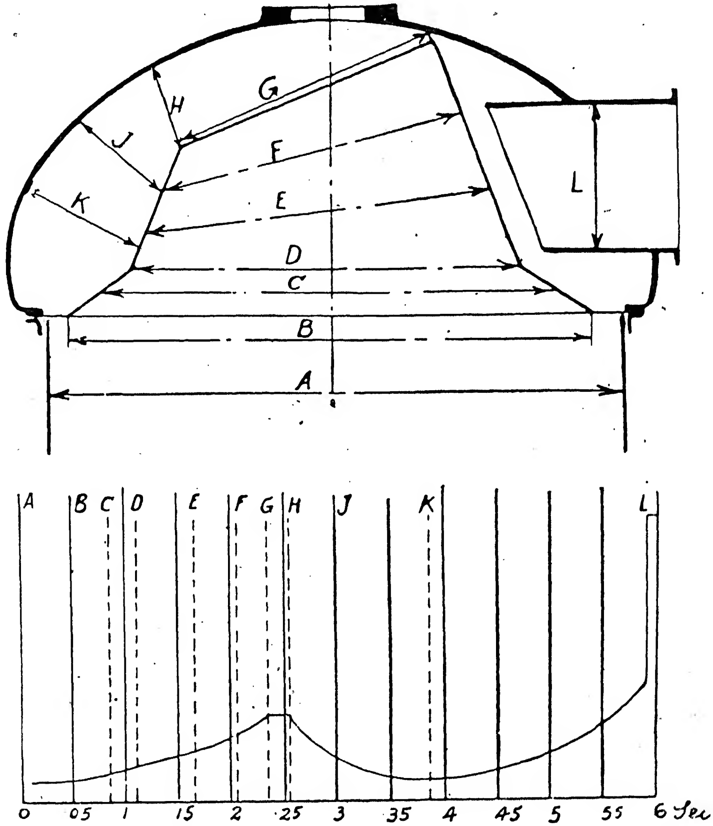


FIG. 168.—Sectional diagram of anti-entrainment device.

syrup to the body of the pan, a series of openings is provided in the flange which forms the base of the funnel. Such openings are kept to the side farthest away from the outlet to the condenser, the flange being set with a sufficient slope to promote effective drainage.

Reference to Fig. 169 will show the care which has to be devoted to the important question of entrainment, and it will be seen that an important feature of this anti-entrain-



VELOCITY DIAGRAM

Scale of Velocity 5 to 10 ft. per sec. = Vertical lines.
Scale of Time $6\frac{1}{4}'' = 1$ second.

Velocity at	Feet per Sec.
A	8
H	40
K	108
L	130

Fig. 169.—Velocity diagram of an anti-entrainment arrangement similar to that shown in the preceding illustration.

ment scheme consists in the proper arrangement of the successive areas of the passage through which the vapour is led. In the first place they should always be of ample size, so as to not constrict the flow of vapour, but they

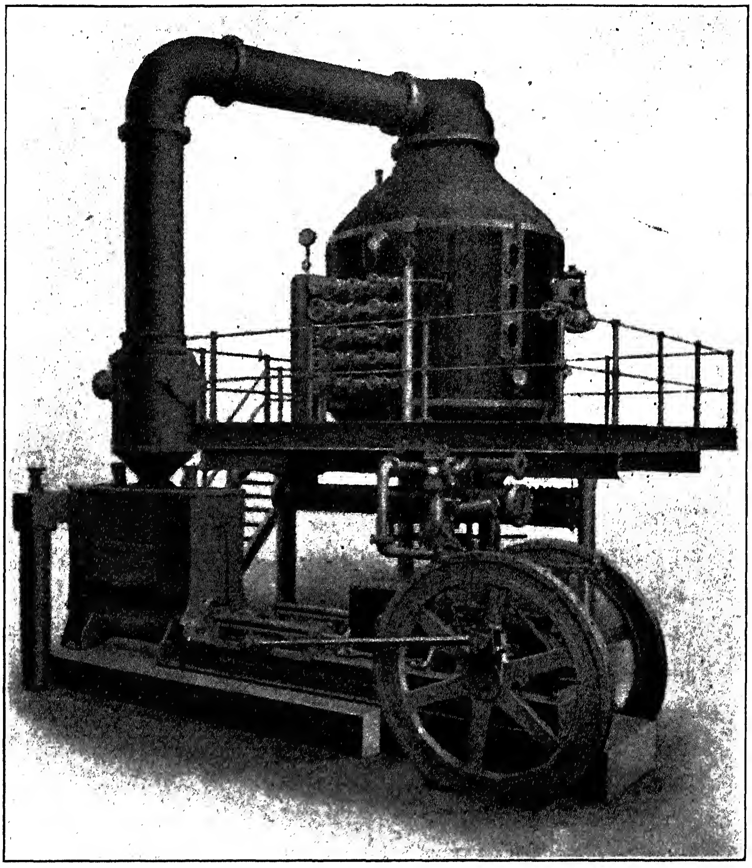


FIG. 170.—Complete vacuum-pan installation worked in conjunction with an ordinary jet-condenser and double-acting displacement vacuum pump.

should also be so proportioned that, on escaping from the orifice of the funnel, there will be a sudden drop in the velocity of the issuing vapour, so as to cause a precipitation of the syrup which would otherwise have been carried

onwards. The velocity diagram in this illustration explains the aim and object of all anti-entrainment arrangements, and indicates in general the principles which control their design, whatever may be the precise form in which they are made, while some of the preceding illustrations of the vacuum pans already given show other methods of attaining the above objects.

Up to this point attention has been confined to the body of the pan itself, and its immediate fittings. It is now desirable to notice the leading accessories, without which a vacuum-pan plant would be incomplete. Fig. 170 gives a general view of a complete vacuum-pan installation, and shows the pan associated with these various accompaniments. The large horizontal vapour pipe, which leads out of the dome, bends downwards to the condenser, within which the hot vapour is brought into contact with the cold injection water and condensed. The conical base of the condenser stands in this case upon the top of the vacuum pump, which maintains a sufficient vacuum within both pan and condenser. The pump has to deal with the volume of the whole of the condenser water in addition to the air and condensed vapour. In many cases, however, a Torricellian or barometric condenser is employed, as shown in Fig. 171, when, as explained in connection with multiple-effect evaporators, the water is not drawn away through the pump itself. The duty of the pump is thus confined to dealing with the air and uncondensed gases arising from the contents of the pan. This barometric system is now much preferred for use in large central factories.

The simpler forms of condenser used to be more usually preferred, when they were most frequently supplied as ordinary jet condensers. As a rule these elementary appliances give excellent results, more especially when water is abundant, and by virtue of their extreme simplicity they

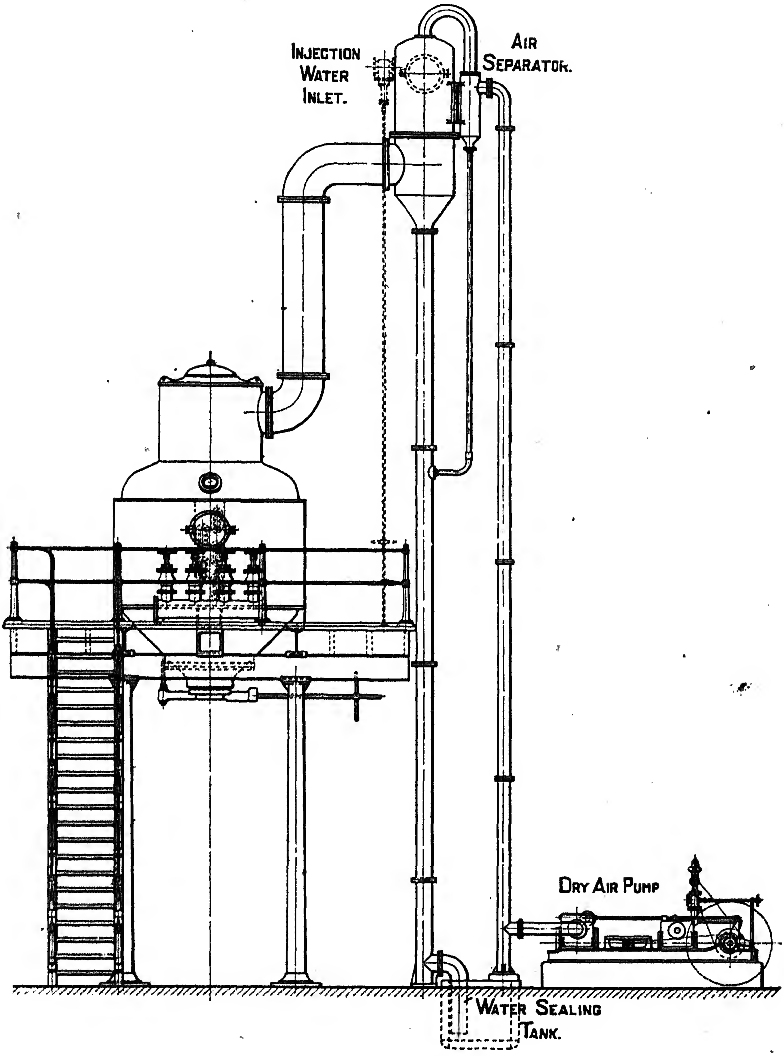


FIG. 171.—Complete vacuum-pan installation worked in conjunction with a Torricellian condenser and dry-air vacuum pump.

avoid all dangers arising from the use of more complicated apparatus which might have to work with comparatively foul water containing a considerable proportion of foreign

bodies. In certain localities, however, water is scarce, and it becomes necessary to employ a condenser of a more complicated type. Excessive quantities of injection water are not indispensable, the chief point in view being the complete intermixture of moderate quantities of the former with the condensable vapour arising from the contents of the vacuum pan. To effect this thorough intermixture, it is desirable to break up the body of incoming water into the minutest globules and thinnest films possible by means of suitably arranged breakers, which occupy their proper positions within the body of the condenser in the form of either perforated or unperforated water trays or ledges, through or past which the treated vapour passes in an upward or downward direction. Owing to the extreme attenuation of the vapour thus dealt with, it is best not to attempt the institution of a system of counter-currents between the two bodies when intermixed unless very special precautions are taken. The downward water current has a tendency to overpower and check an upward vapour current, and thereby nullify the results that should otherwise be obtained by a properly arranged apparatus, of which the efficacy should be shown by the attainment of a satisfactory degree of vacuum. When counter-current condensers are employed, they may assume the form of horizontal multitubular surface arrangements, the water passing backwards and forwards from end to end and from bottom to top of the condenser through the tubes, while the vapour is similarly led downwards through the body of the vessel by an arrangement of baffles, which ensures an equal number of counter-passages of the vapour, thus enabling the action of the water to take proper effect (see Fig. 78, in which, acting as a condenser, water will take the place of the juice). It will thus be readily understood that a scarcity of injection water may at times involve the use of

larger and more complicated and expensive condensers, the use of the simpler forms of jet condensers being preferred when there is a plentiful supply of injection water. It should, however, be observed that in the case of the use of the surface condenser just described, the vacuum pump does not have to deal with the disposal of the injection water, but, as in the case of the use of a Torricellian condenser, simply has to cope with the condensed vapours and uncondensable gases. In the case of the ordinary jet condenser, shown in Fig. 170, the mixed water, air, and uncondensable gases pass through the bottom outlet of the condenser into the suction chamber of the vacuum pump, and this final accessory of the installation has now to be described. It may be of either the vertical or horizontal type, according to circumstances, the latter form predominating in general use.

The first class of pump to be noticed is seen in Fig. 172, and is intended to deal with the whole of the mixed contents of the condenser. It is thus termed a "drowned" or "wet" air-pump, in contradistinction to the "dry" air-pumps used in conjunction with the Torricellian condensers. The mixed products first enter the pump via the suction branch A, filling the suction chamber B with water and rarefied gases. The inlet A and the chamber B are so arranged that the uncondensable gases always have the fullest chance of remaining uppermost, without having unduly to force their way through the accompanying water. In this instance the brass pump bucket or piston F works backwards and forwards in the brass-lined pump barrel H through the agency of an attached steam-engine, and is now supposed to be moving, in the direction of the arrow, towards G. By this movement of the bucket F a vacuum is established in each one of the suction compartments B, D, and E, in the front half of the pump, and thus the contents

of the condenser are drawn through the suction valve C, the water falling downwards towards E, the air and incondensable gases keeping uppermost towards D. When the reverse stroke of the piston F takes place, and it returns

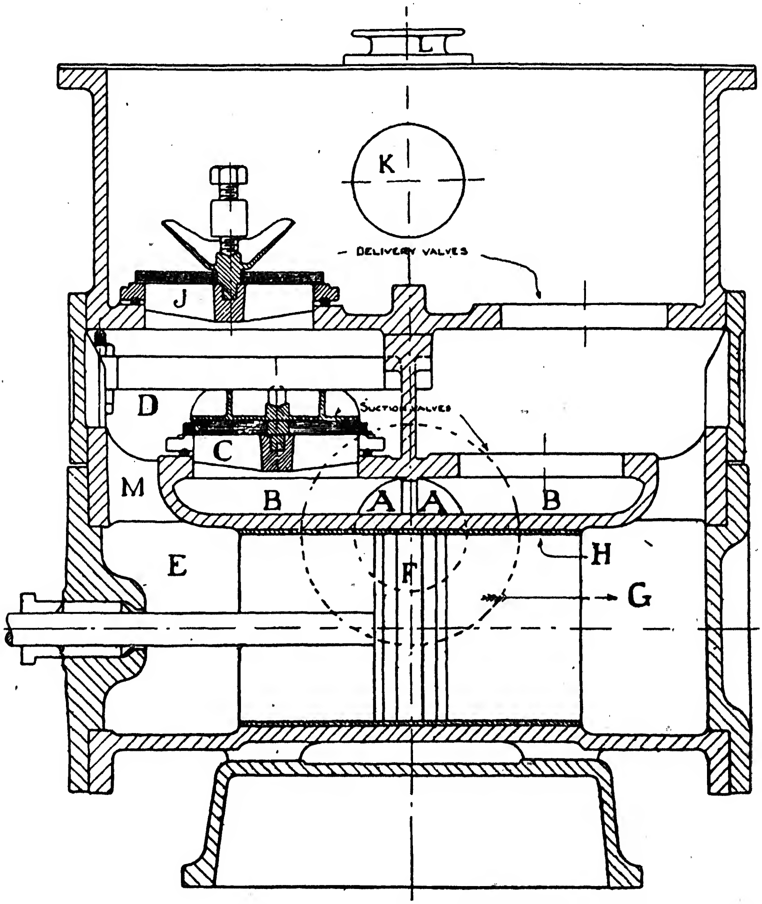


FIG. 172.—Section of double-acting horizontal vacuum pump of the bucket type.

towards E, the suction valve C closes instantly, and the compressed air and gases, together with all surplus water, are ejected through the delivery valve J, the water running to waste through the outlet K, while the air escapes through

the air pipe L. This describes the movements and effects which result from two consecutive and reversed strokes of F to the front of this bucket; and, as the pump is double acting, similar effects alternately take place in the back half towards G. That is to say, for each complete revolution of the engine both ends of the pump have been utilised and operated in reverse order. It will be noticed that the suction spaces of the pump chambers are considerably in excess of the total displacement effected by each stroke of the pump bucket, and herein lies a characteristic feature which controls the design of such apparatus. These considerable clearances contain at all times sufficient water to maintain a water-seal, the level of which should never descend below the level of the middle height of the passage M during those periods when there is a vacuum in the opposite end chambers of the pump. Proper attention to this point prevents the possibility of air leakages past the bucket F, and renders it quite unnecessary to keep it as tightly packed as would otherwise be imperative. The presence of a sufficient excess of water in the compartments D, M, and E ensures the complete ejection, without remainder, of air and gases through the delivery valve J, an attainment which is essential to the satisfactory working of the pump.

Another class of horizontal vacuum pump which may now be considered is shown in Fig. 173. It also is a drowned or wet air-pump, and in some respects is not altogether dissimilar to the apparatus just described. Its chief characteristic, however, consists of the special form of plunger P, which takes the place of the bucket F of its predecessor. The proper maintenance of the efficiency of a vacuum pump is a matter of great importance, and any device which minimises the amount of supervision requisite is always welcomed by the engineer of a sugar factory.

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In the case of the majority of bucket pumps, special attention has to be paid to the packing of the buckets, and the particular form of pump now under consideration has for one of its chief objects the doing away with the necessity of any packing whatever. Packing rings and gasket are herein supplanted by the action of the water in which the plunger P is at all times completely immersed. The latter is simply made so as to be an easy fit in the "bush" or "sleeve" S, thus moving backwards and forwards through it without undue friction or the excessive expenditure of

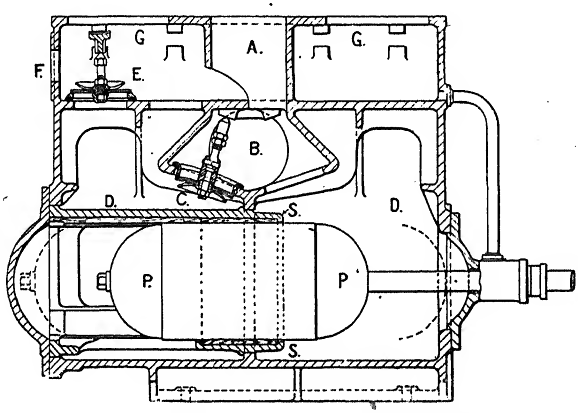

Fig. 173.—Section of horizontal double-acting "displacement" vacuum pump fitted with torpedo plunger.

propelling power. Its weight also is usually proportioned to match its displacement, and it therefore practically floats in the surrounding water. Air leakages, in vacuum vessels of all types, are most insidious drawbacks to the attainment of a satisfactory vacuum, the slightest crevice frequently proving a sufficient obstacle to the insurance of good results. Therefore, it will be seen that a trifling air passage between the plunger and the sleeve, if not sealed in some way or another, is certain seriously to prejudice good working results. Such seal is effectually supplied by

the water in which the plunger is completely immersed, and efficiency, combined with freedom from undue friction, is secured. Generally speaking, the action of the pump, as a pump, is pretty much on all fours with the bucket pump already described. The mixed contents of the condenser enter the suction chamber through one or other of the two inlets A, B, and, passing through the suction valves C,

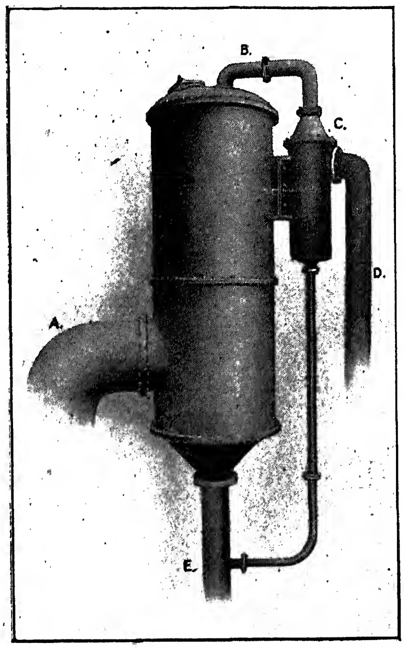

FIG. 174.—Torricellian condenser fitted with patent separator.

enter the main pump chambers D, towards whichever chamber is waiting to receive them. Upon the return stroke of the plunger they are ejected through the discharge valves E, the water flowing away to waste through F, while the air escapes through openings at G.

The above types of vacuum pumps are constructed in various forms, both horizontal and vertical, which com-

prise various subordinate differences as to details; but a careful examination of the accompanying illustrations will explain the essential features which should at all times characterise an efficient apparatus of this description. It is now sufficient to pass on to the consideration of pumps of another class, which are more particularly connected with the use of a Torricellian condenser. Fig. 174 is an exterior view of the latter accessory, which is also seen in its relative position in Figs. 133 and 171. It is a counter-current condenser, and its interior arrangements are so constructed as to prevent the falling water from overpowering the upward vapour current. This safeguard is effected by causing the water to pass through the condenser in the form of a series of cylindrical films or water-curtains through which the air and uncondensable gases can pass with comparative ease, while at the same time the vapour is effectively acted upon by the water. The vapour and uncondensable gases from the pan enter the condenser by the

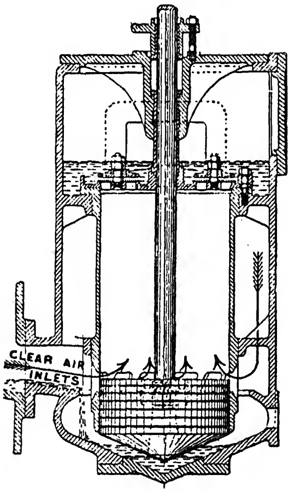

FIG. 175.—Special form of vertical vacuum pump.

branch A, and the former is condensed, the uncondensable gases leaving by the connection B. They then enter the separator C, ultimately passing away to the dry air pump by the pipe D. The condensing or injection water enters near the top of the vessel, leaving it by the tail-pipe E, thus taking an altogether different route from that followed by the air and gases, leaving the latter alone to be dealt with by the pump, which is thus styled a dry air pump. The precise manner in which the water leaves the condenser

without the assistance of a pump is clearly seen in Fig. 171. The long tail-pipe E must be fully 34 feet in length from the point where it joins the bottom cone of the condenser to its base, and its lower outlet branch is sealed by the water contents of the overflow tank. Thus a column of water, due to atmospheric pressure, approaching 34 feet in height above the surface of the water in the sealing tank, is maintained in the tail-pipe, and so protects the vacuum in

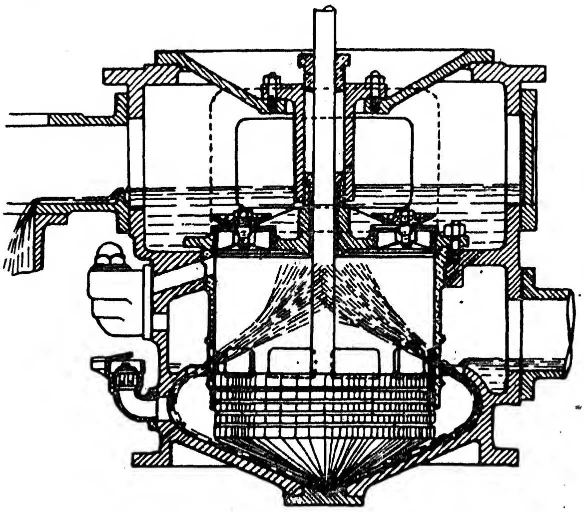

FIG. 176.—Another section of the same vacuum pump, showing the characteristic action of the pump plunger.

the condenser, at the same time permitting all excess water to flow freely into the tank, whence it overflows into the factory drainage channels.

The first class of pump to be noticed in connection with the above condenser is shown in Figs. 175, 176, and 177. In the first illustration the pump bucket is descending, and the point of the cone is entering the small amount of water which is generally present for the purpose of ensuring the highest efficiency of the pump. This entry is effected

without shock, and a high velocity is thereby given to this water, causing it to be carried up through the ports situated in the lower portion of the barrel, as seen in Fig. 176. This illustration also shows that the lower part of the pump casting is so shaped that it will control the direction in which the water spurts, the latter passing through the lower parts of the ports, the upper portions of the same being left clear for the perfectly free entrance of the accompanying air and gases. The return or upward stroke of the

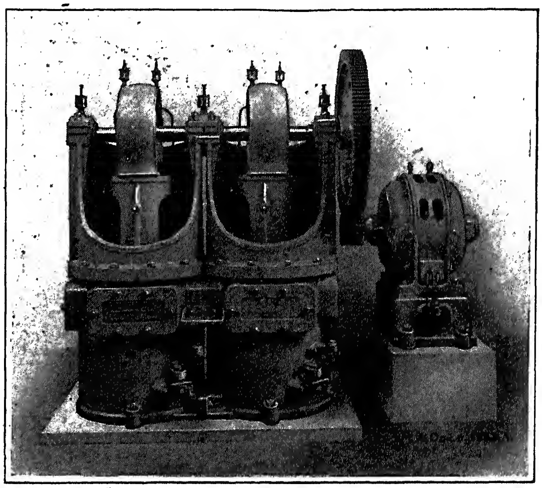

FIG. 177.—General view of an installation of the vacuum pump shown in Figs. 175 and 176.

bucket closes the ports, and the rising water followed by the bucket discharges the air and excess water through the valves at the top of the pump. The absence of suction valves in pumps of this class is a great convenience, and causes simplification of construction. A clear inlet for the incoming air is also a point of great importance, increasing the amount of air that a pump of given diameter will throw, at the same time ensuring the attainment of a good vacuum. Fig. 177 gives a general view of a pumping installation of

this class, in which it is generally preferable to employ two or more pumps of smaller diameter rather than one pump of larger proportions.

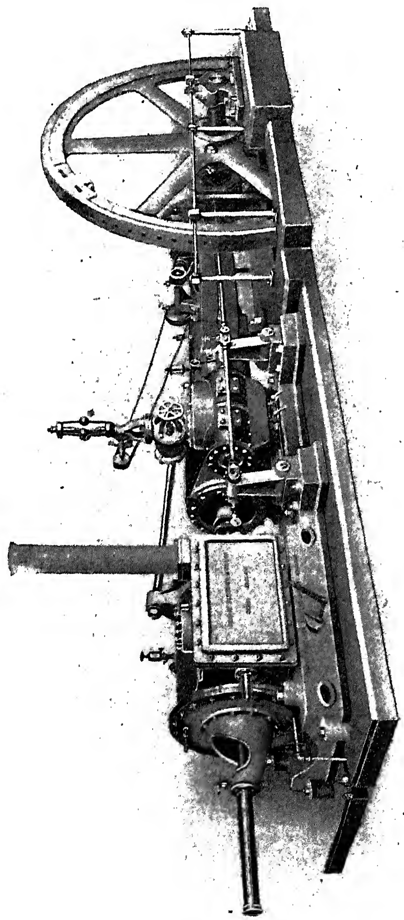

FIG. 178.—Dry slide-valve air-pump for maintaining the vacuum in Torricellian or barometrical condensers.

Fig. 178 shows the general features of the next and last class of vacuum pump which it is necessary to notice. This variety is only used in connection with Torricellian condensers, and is known as a dry slide-valve air-pump. The

steam cylinder which actuates the pump is placed nearest the fly-wheel shaft, while the outer cylinder performs the duty of a pump. The latter in its action is, in fact, a reversal of the steam-engine cylinder, a special arrangement of the slide-valve being driven by an eccentric which gives it a positive action, coupled with a high resulting vacuum

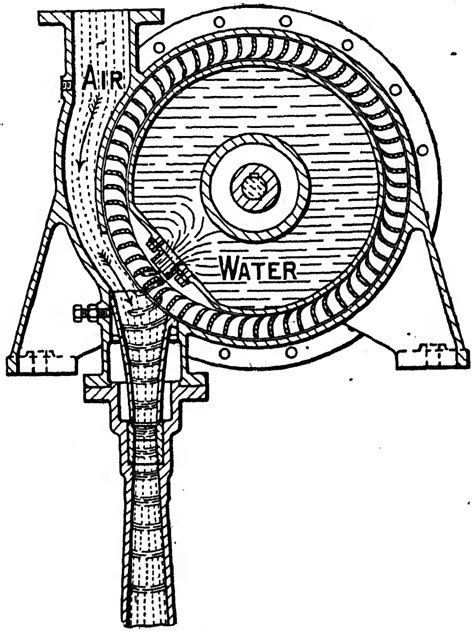

FIG. 178A.—Leblanc rotary air-pump.

and consequent efficiency. The use of the separator C, seen in Fig. 174, is more especially desirable when pumps of this class are employed.

When Torricellian condensers are installed the Leblanc rotary air-pump (Fig. 178A) may be employed, which, with the improvements made since its first adoption, compares favourably with the best types of reciprocating air pumps. It acts on the intermittent water-plug or piston principle, as shown in the illustration, which is more efficient than

entrainment by surface friction, and in most cases can be operated from the same water sources supplying the condenser injection-water.

Similarly, the multijector air-pump may be employed (Figs. 178B and 178C).

The arrangement of the simple type of multijector is shown in Fig. 178B, from which it will be seen that the pump is formed with two stages consisting of two multiple nozzle ejectors connected in series and constructed as a simple self-contained unit.

Each ejector is comprised respectively of a steam chest, A, A2, and an air suction chamber, B, B2, a group of convergent-divergent steam nozzles C, C2, and a convergent-divergent compression pipe D, D2, terminating in a diffuser pipe E, E2. The air inlet branch F is connected to the condenser or other vessel to be evacuated, and the operating steam supply is connected to the main steam inlet G located on the second stage steam chest. A branch steam pipe H, fitted with a stop valve, conveys a supply of steam to the first stage nozzles.

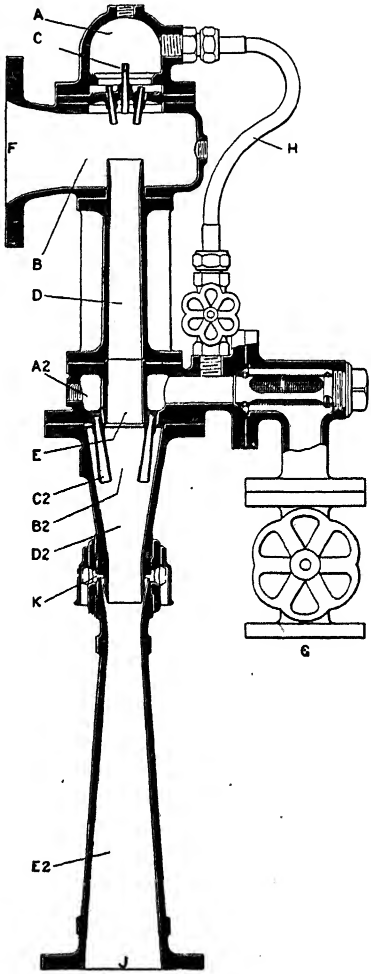

FIG. 178B.—Multijector air-pump or exhauster, simple type.

The operating steam entrains the air by friction. During entrainment it is the velocity of the steam which is utilised, and it is due to the high velocities of the operating steam and evacuated air that the multijector is so conveniently small and of light weight.

The principle of operation consists of projecting steam at high velocity through the group of multiple nozzles into the compression pipe, the first stage group of nozzles C giving the initial motion to the air and gases. These are partially compressed in the first stage ejector and attain considerable velocity as they flow to the second stage, where the requisite final velocity is imparted by the second stage group of nozzles C2. The mixture, on passing through the second stage compression pipe, D2, enters the diffuser pipe, E2, where the kinetic energy is transformed into useful work in overcoming the atmospheric pressure at the discharge end J.

At the throat of the diffuser pipe E2, an auxiliary air inlet, K, is provided and arranged to be in permanent communication with the atmosphere if the multijector is discharging into the atmosphere or against a very low pressure head, whilst in other cases it would be in communication with the same chamber into which the multijector may be discharging.

The intermediate condenser type of multijector is arranged similarly to the simple type, but with the addition of a small compact jet condenser, made of cast iron, as shown on Fig. 178c. The general principle of operation is also the same, but the air and gases from the first stage ejector are discharged through the diverted diffuser pipe E into the jet condenser at K. Passing into the condenser, the steam used in operating the first stage ejector is intimately mixed with a water spray issuing from nozzle L, and the injection water and condensed steam is drained from the condenser at

N. The cooled air and incondensable gases are withdrawn through M by the second stage ejector, and the mixture

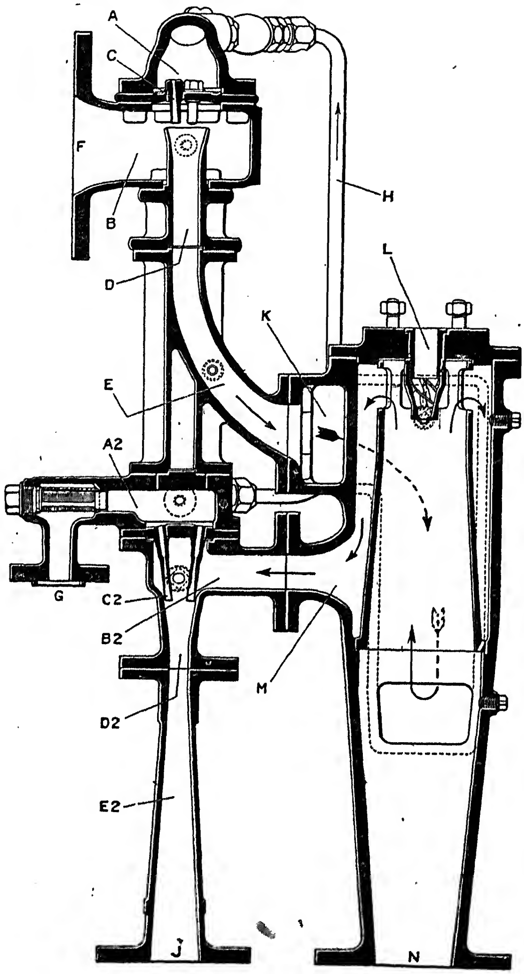

FIG. 178c.—Multijector air-pump or exhauster, condenser type.

passes through the compression pipe D2 and enters the diffuser pipe E2, where the kinetic energy is transformed into useful work in overcoming the atmospheric pressure.

For the same duty, the intermediate condenser type requires about half the amount of operating steam taken by the simple type. Where the heat contained in the discharged mixture of steam and air cannot be utilised, the intermediate condenser type should be used, but where the heat contents of the discharge can be utilised, either type may be used, according to the conditions.

The principle upon which the vacuum pan is mainly worked is that of gradual crystallisation as concentration progresses. The syrup as it comes from the evaporator stands at a density, as already mentioned, of about 30° Bé., corresponding to the specific gravity of 1·260, and contains some 45 per cent. of water. In some cases, especially in the manufacture of grocery sugars, syrups are reheated and filtered before going to the vacuum pan.

In starting the vacuum pan, when a vacuum has been obtained, a certain quantity of syrup, varying according as a large or small-grained sugar is desired, is drawn into the pan, and boiled down at a vapour temperature of 135° Fahr. or thereabouts, until a fine cloud of crystals is seen, when the syrup thus concentrated is viewed in a thin film. The temperature of the pan is then raised so as to secure the resolution of the smaller crystals, and consequent uniformity of grain. This stage of the boiling, which is called "graining," having been completed, the boiling temperature of the pan is again lowered and syrup gradually introduced into the mass. This can be done either by continuous or intermittent feeding. As concentration proceeds, if the operation is carefully carried on, the separated sugar is deposited on the surface of the already formed crystals, which thus gradually grow in size as the pan fills up with sugar. When sufficient syrup has in this way been drawn in to supply a complete filling of the pan with massecuite, as the mixture of sugar grain and molasses is termed, the supply is

stopped, and boiling is proceeded with until the massecuite has reached the proper consistency. This point is generally arrived at when the proportion of water present has been reduced to 5 per cent. or 7 per cent. The striking orifice of the pan is now opened, and the contents allowed to fall into either "crystallisers," which are described below, into movable or fixed tanks, or into the pugmills of the centrifugals for immediate curing.

The operation of crystallisation is not difficult, provided care is taken. The chief point which requires attention is regulation of the supply of juice in relation to speed of evaporation of the pan, so that the sugar is not separated from the incoming juice in the form of a secondary batch of crystals, but is deposited on the surface of the grain already formed. Should, however, this not happen, and a fine grain be formed among the larger crystals, the sugar will be cured with difficulty in the subsequent centrifugal operation. Such a grain is called "false" grain, is the bugbear of pan-boilers, and requires much manipulation to remove. To secure a large, well-shaped crystal, a minimum amount of grain should be formed in the first instance, while during boiling the grain should be kept, as it is technically termed, "open"—*i.e.*, there should be plenty of "mother liquor" between the crystals. This, of course, increases the danger of false grain, and is a course which cannot be adopted with gummy juices. Should the massecuite be kept "close"—*i.e.*, with a high proportion of grains to the cubic inch—the resulting crystals will be small and badly formed, through the breaking up from attrition of the twin prisms which form the well-shaped sugar grain.

In order to obtain a maximum quantity of sugar in one operation, it is usual to add molasses to the later syrup charges of the pan, gradually increasing the proportion of molasses to syrup and using molasses only for the last

charge. In this way, in addition to the syrup sugar, some of the sugar in the molasses is also obtained in the form of crystals, while the use of molasses, by increasing the proportion of uncrystallisable mother liquor, and by thus giving rise to greater fluidity in the massecuite, enables greater concentration to be effected than would otherwise be the case. The mother liquor which has been separated from the crystals in the form of molasses contains a large amount of sugar which is recoverable by further concentration. To obtain this, the molasses, after suitable treatment, is boiled down in the pan to the required density, a higher temperature being employed than with syrup sugar, so as to avoid the formation of grain, and at the same time secure a proper degree of supersaturation. The contents of the pan before the introduction of crystallisers were then struck into coolers, in the same way as with muscovado sugar, granulation being complete in from four to ten days. After the sugar has been separated from the molasses massecuite by the centrifugals, the resultant molasses, if of sufficient quality, is then again boiled and crystallised in a similar manner.

With the view of obtaining a lessened quantity of, or of doing away altogether with, molasses sugar as an ultimate product, it is customary to use the latter for grain for the first sugar. This is usually done by mixing it with syrup sufficiently concentrated in the evaporators to ensure that little solution of the sugar takes place. The mixture is then drawn into the pan, and the grain thus given built upon as already described. A similar result is obtained by concentrating syrup in the vacuum pan to a point short of granulation and by drawing the dry sugar into it. In each instance sufficient solvent power exists on the part of the syrup to dissolve fine grains which might interfere with the quality of the subsequent sugar. It is a *sine qua non*, however, in

point of view of the amount of sugar recovered, that the syrup with which the sugar is mixed should not be so dilute as to dissolve an excessive quantity of the sugar. By the adoption of either of these methods, not only is one sugar alone obtained as an ultimate product, but much of the time occupied by graining in the ordinary manner saved. With the manufacture of grocery sugar, however, this method of working is out of the question, as a perfect and gradually formed initial grain is required to give good ultimate results.

A common practice among sugar-boilers is to make what is technically known as a "cut." Instead of discharging or "striking" the whole of the contents of the pan at the first filling, half is struck out and the pan again filled. In this case molasses is not added to the syrup at the first filling, but the molasses from the first "cut" is used in the subsequent filling, a control being thus given as to the quality of the molasses used.

Of recent years the process of crystallisation has been considerably extended by the introduction of "crystallisers," by means of which the working up of molasses and syrup sugars has been greatly facilitated. Before describing these apparatus in detail, it will be desirable to examine Fig. 179, in order that their special functions may be more clearly understood. The vacuum pan is here seen in the upper story of the factory. Upon being emptied, its contents may be directed at will either into the "strike mixer" situated immediately beneath the pan, or into the "crystallisation-in-motion" plant to the right-hand side of it. If the former course is adopted, the massecuite proceeds to the centrifugals, which are situated on the ground floor, without further treatment. If the latter, the process and machinery now to be described are brought into play. It may be observed that the modern crystallisation-in-

motion plant is nothing more nor less than a development of the "oscillator" shown in Fig. 164, and used many years ago in the manufacture of muscovado sugar. It has, in fact, been in operation for upwards of fifty years, though it has only been generally employed during the last twenty. The mechanical advantages brought forward in connection with its use are so apparent, and so modern in general conception, that, even though the technical advantage of

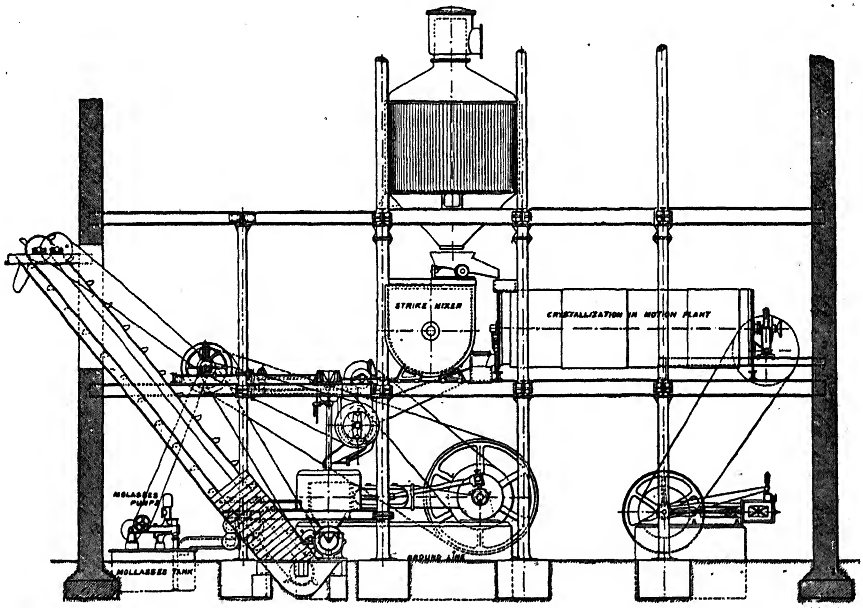

FIG. 179.—General arrangement of vacuum pan, crystallisers, and centrifugals.

crystallisation in motion may under certain conditions be open to debate, the new means of handling massecuite, incidental to the process, will probably remain in evidence for a long time to come in one shape or another. Crystallisers may be either open or closed, either steam-jacketed or unjacketed, and Fig. 180 shows a battery of these machines of the simpler and open types without jackets. Their

shape and proportions are here shown, and it will be noted that the shaft, which extends from end to end of the interior of the vessels, is fitted with stirrers and driving gear which are actuated by the adjacent steam-engine. The

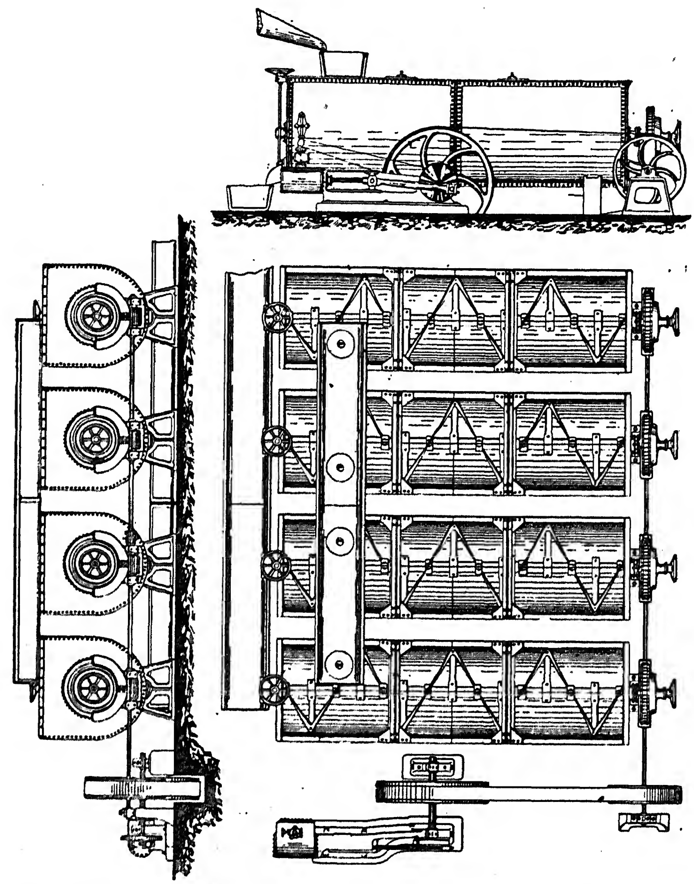

FIG. 180.—General plan of a complete set of open-type crystallisers.

massecuite issues from the vacuum pan into the large receiving gutter placed immediately above the crystallisers, from which it is admitted through plug-holes or valves into whichever vessel is ready for its reception. By the use of

these machines it is claimed that a larger return of marketable sugar crystals is obtained than in the case of crystallisation at rest. From the time the massecuite leaves the vacuum pan up to the moment it enters the centrifugals, the process may be automatic, and a considerable amount of labour entailed by the use of some of the older arrangements may therefore be dispensed with, economy being thus effected. It is also claimed that the crystals from massecuite in motion are larger and more uniform than when

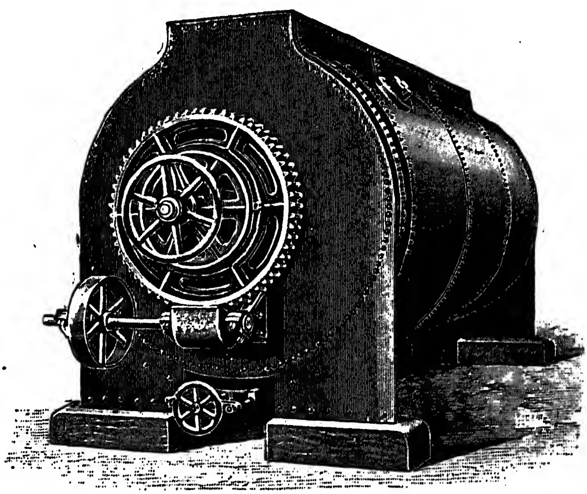

FIG. 181.—Semi-open type crystalliser.

formed from massecuite at rest. The very gentle motion given to the massecuite is just sufficient to build up into a larger grain the cane sugar, which would otherwise be liable to form "false grain," and it likewise ensures a more uniform degree of heat throughout the mass of sugar under treatment. Owing to the lessened likelihood of the presence of false grain, the work of the centrifugals is facilitated and increased, and economy of floor space is effected, coupled with greater general cleanliness. The extent of the stirring

and gentle movement administered to the massecuite may be gathered from the fact that the stirrers usually, on an average, make about one revolution in two minutes. The open crystallisers shown in Figs. 179 and 180 are unjacketed, but when they are fitted with jackets they may be constructed as seen in Fig. 181, when they are termed semi-open crystallisers. These jackets may then be filled either with low-pressure steam or hot water in circulation, and

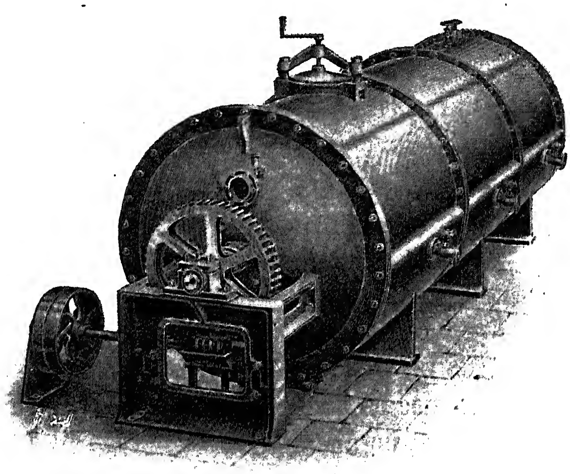

FIG. 182.—Jacketed closed type of crystalliser.

the object of this addition is explained later on. These semi-open crystallisers are frequently used without steam-jacketing.

A more elaborate form of these crystallisers is shown in Figs. 182 and 183, in which the vessels are closed, and are both jacketed and unjacketed. In the case of the closed crystallisers the cylinders, in addition to the usual stirrers and driving gear, are fitted with special charging and discharging valves, man-hole doors, sight glasses, sampling cocks, and pressure and vacuum gauges, together with

connection pipes to the molasses tanks, the steam main, the air-pressure accumulator, and the vacuum pump, as seen in Fig. 183. The crystallisers may thus be connected direct to the vacuum pan, and when the latter is to be discharged the vacuum in it is broken and the vacuum connection to the former opened. The massecuite then passes to the crystallisers by suction. If this method is not adopted, the pan is made to discharge into shoots or conveyers, which carry the massecuite to the man-holes of the crystallisers. With closed vessels the usual method is to keep the massecuite in motion under vacuum, but if the open-air process is used the man-hole doors are left open. The various mountings enumerated above allow of careful and exact treatment and inspection of the massecuite in the closed vessels during the process of crystallisation. When discharging, the connection between the crystallisers and the vacuum pump is closed and the valve to the air-pressure opened, the massecuite being thus forced through suitably arranged pipes to the centrifugals. If the open-air process has been used, the man-hole doors are first closed before air-pressure is admitted to the cylinders. This system of closed crystallisers permits of greater latitude in the matter of the arrangement of a complete plant of vacuum pans, crystallisers, and centrifugals, and, by dispensing with gravity, saves headroom, and enables the special requirements of particular cases to be more readily met without making considerable alterations to existing buildings. Fig. 183 shows the general arrangement of such an installation.

Considerable difference in actual practice occurs with the use of crystallisers. Their great advantage is the opportunity given for working up molasses with syrup massecuites in a manner which cannot be done in the vacuum pan. The massecuite from syrup can be boiled

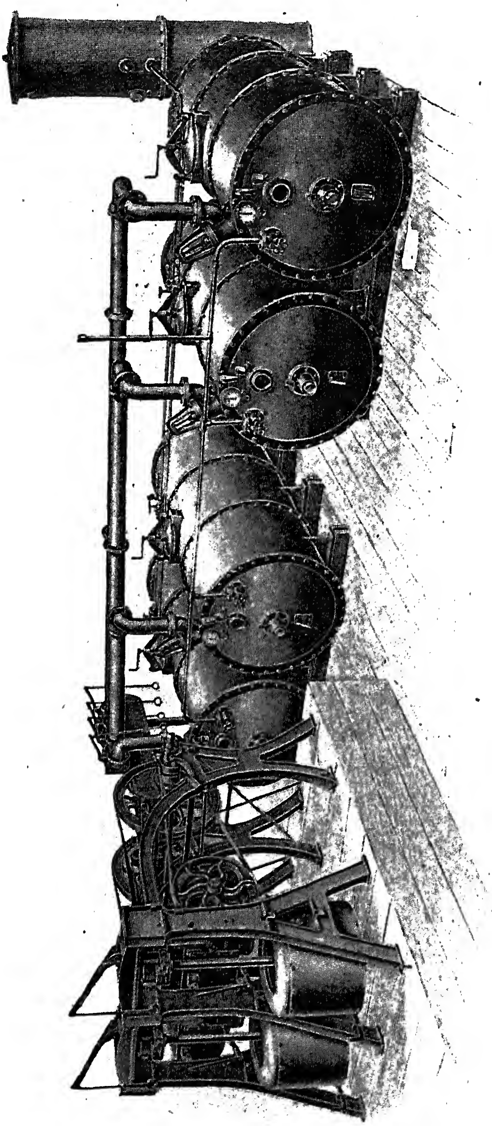

FIG. 183.—Installation of a battery of four closed crystallisers in conjunction with a pair of Weston's centrifugals.

down in the crystallisers to such a degree as to make it otherwise impossible to remove it from the vacuum pan. Large quantities, 20 to 25 per cent., of hot molasses are then drawn into the latter and thoroughly mixed with the massecuite, further concentration is effected, and the resultant massecuite transferred to the crystalliser, by gravitation in the case of the open, and by suction with the closed, crystalliser. The mass is then kept in motion as it slowly cools, this operation being retarded, in the case of the jacketed crystalliser, by the use of hot water in the jacket, the formation of "false grain" by too rapid cooling of the supersaturated molasses in contact with the sides of the crystallisers being thus prevented. With such a quantity of molasses present, were the massecuite allowed to cool at rest, this would inevitably occur, and it is here that the great value of crystallisation in motion comes in.

The molasses from such sugar is either boiled and struck into cooling tanks as already described, the sugar obtained therefrom being remelted or used for "seed," or grain, for the first sugar, or run away to the distillery or shipping tanks, the quotient of purity of the molasses determining the course to be adopted. What this determining quotient is must be decided by the condition of the juice, as the nature of the foreign bodies present, especially the organic salts, as well as the quantity, materially influence the crystallising power of the cane sugar.

Another method of using crystallisers is to devote but little time to the first sugars, and to concentrate their work on the molasses products. As the presence of grain is essential, syrup is added to the molasses in order that graining may be effected in the vacuum pan. The resultant sugars are frequently mixed mechanically with the first product.

It must not be considered that crystallisers *per se*

increase the extent of crystallisation of the sugar. Massecuite boiled to the same degree of concentration and cooled at rest would contain the same amount of crystallised sugar as when crystallisers are used, but would not give the grain in a suitable form for curing. The function of crystallisers is to enable massecuites to be manipulated with much greater ease, celerity, and efficiency than would otherwise be the case. By their aid a considerable proportion of the sugar in the molasses can be converted into high-grade sugar in one operation, while the period of crystallisation of second products is much accelerated.

From the variation in the manner of working vacuum pans and crystallisers, it is difficult to lay down the quantity of each class of merchantable sugar which is obtained for every 100 lbs. of sugar that has come into the factory in the form of juice. With the standard of cane juice, however, which has been taken all along, 88 per cent. of chemically pure sucrose, or 91·6 per cent. of 96° sugar, is obtained in the form of refining crystals. Formulæ are frequently given by which the possible extraction of any given sample of cane juice can be calculated, based on the proportion of uncrystallisable sugar and the "quotient of purity," or relation of the crystallisable sugar to the total solid content, of the juice. As the working qualities of the juice depend upon the nature as well as the amount of the impurities present, such formulæ are not invariably a guide to extraction, and although they may be approximately accurate with reference to the juice of a particular factory, or description of cane, it in no way follows that their application is generally correct.

Various methods are in use for rapidly emptying or removing the massecuite from the interior of the vacuum pan. Such discharge usually takes place by gravitation alone, but in the case of the closed crystallisers the move-

ment may be accelerated, as already described, by suction due to the action of the vacuum maintained in these vessels. In some systems compressed air is admitted to the upper portion of the vacuum pan to hasten the downward discharge of its contents, and helical screws are occasionally employed to force out the massecuite. A rapid emptying of the pan increases its capacity for the performance of its specific duties, and when one or other of these accelerators is not in use, it is no uncommon incident for a large-sized pan to take from one to two hours to discharge a strike of highly concentrated massecuite. The above helical screws are sometimes advantageously used continuously the whole time the pan is performing the work of final concentration and granulation, thus maintaining a certain and sufficiently rapid downward circulation in the central passage-way of the pan, with a consequent general improvement of the circulation of the massecuite throughout the entire body of the vessel, thus largely increasing its output in a given time. Hitherto the question of the treatment, on its way from the vacuum pan to the centrifugals, of this viscid magma of sugar-crystals and molasses has been considered solely in connection with the intermediate employment of the crystallisation-in-motion installations just described. The latter have, however, only come into general use during comparatively recent years, and it was, prior to their introduction, the custom to strike the finished contents of the vacuum pans into fixed or movable tanks, from which the massecuites were conveyed either by gravitation or mechanical means to the pugmills of the centrifugals. A common and convenient form of movable tank adapted to the handling of first massecuite is shown in Fig. 184. Its capacity should be about 600 gallons, and, as it stands on the traverser, it will be noted that it consists of a strong wrought-iron tank-body, con-

structed of riveted plates, the tapering shape of this receptacle being arranged to facilitate the discharge of the contents into the pugmill attached to the centrifugals. A factory furnished with massecuite tanks of this description has tram-rails running under the vacuum pans, and leading thence to both the storage chambers and the centrifugals.

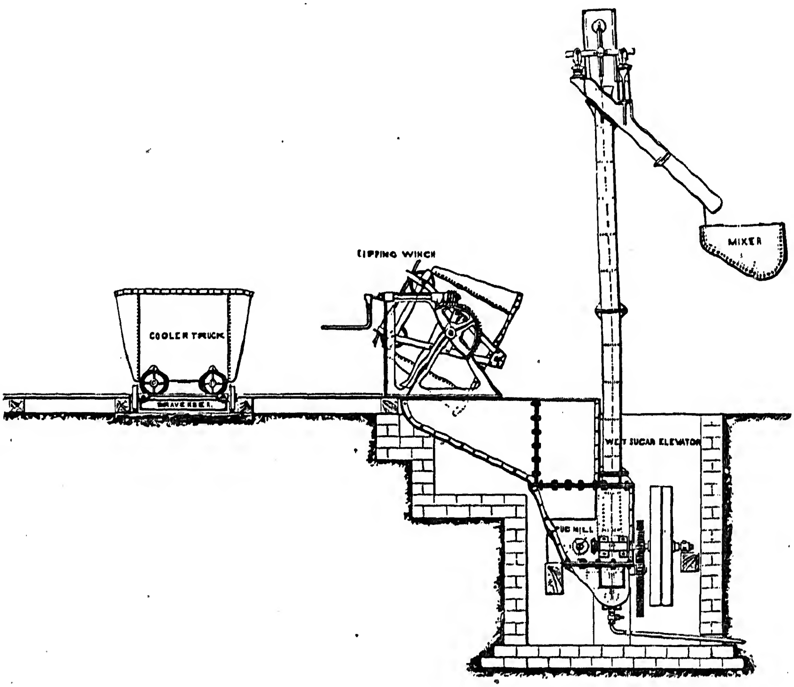

FIG. 184.—Showing the mechanical handling of massecuite in connection with large-sized cooler trucks.

Such tram-lines are supplemented by the necessary turntables and traversers, and, when it is the practice to record the weight of the massecuite, a weighing machine is also installed in a suitable position. This illustration gives all the leading and essential details of such an installation, and shows how the tank may be emptied by the aid of a tipping winch into the large receiver, at the bottom of which a

pugmill is placed. The latter is usually a machine of considerable strength, and its duty is to reduce the solidified massecuite to a homogeneous consistency suitable for treatment in the centrifugals. The resultant magma is then raised by the wet sugar elevator to the mixer, whence it is withdrawn in intermittent batches to the centrifugals as required.

Another species of tank for first massecuites which was once a great favourite consists of truncated cone-shaped vessels, each of about 30 gallons capacity. These were filled from the pan by means of suitably arranged gutters furnished with a series of numerous plugs and outlets, and, as filled, the tanks were picked up by a special form of hand-truck and conveyed to the storage chambers, subsequently proceeding, in due course, to be emptied into the pugmills of the centrifugals. The massecuite in these small boxes should be ready for curing in a few hours, and Fig. 185 shows how they are then transferred to the pugmills, the discharge being facilitated by the use of compressed air conveyed from the compressor through a flexible pipe which can be attached to a suitably prepared plug-hole in the bottom of the bucket. The illustration is a complete diagram of a massecuite and sugar-drying installation as worked in connection with this small class of tank. This kind of tank, though it gives good results with first sugars, is quite unsuited for molasses products, on account of the cooling being too rapid to allow of suitable granulation. For molasses sugars and sugars of low grade a very suitable strike-tank consists of the receptacle shown in Fig. 186. This consists of a small wrought-iron tank holding some 300 gallons of massecuite. It is fitted with two wheels behind, and a pivoted guiding-wheel in front, which enables it to be transported readily along a suitably level floor from the vacuum pan to the storage chambers,

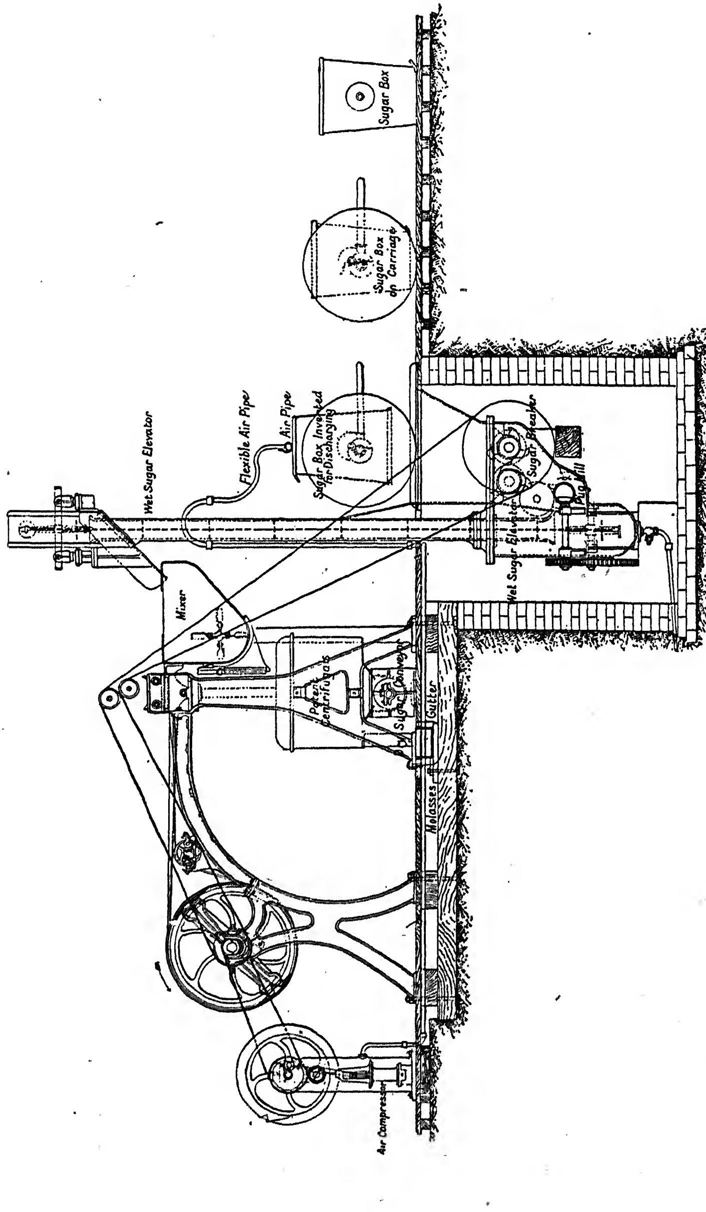

FIG. 185.—Showing the mechanical handling of massecuite in connection with small-sized sugar-boxes.

and later on from the latter to the centrifugals. This description of tank is filled by means of a cock and pipe attached directly to the discharge valve of the vacuum pan. The smaller the tank the quicker the crystallisation, but the size given above is the lowest compatible with good work in the case of molasses sugars. When low-grade massecuites are struck into fixed tanks placed on the same level as the centrifugals, a "magma" pump is commonly used for their transference to the pugmills, and this description of pump is shown in Fig. 187. It may be either belt-driven or steam-driven, as seen in the picture, and is double acting.

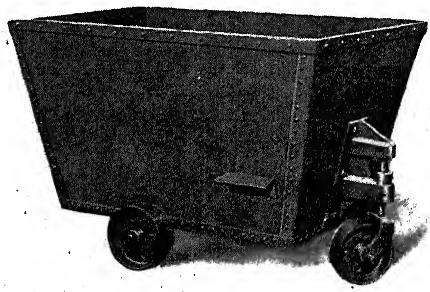

FIG. 186.—Strike-tank for the reception of low-grade massecuites.

It has specially large valve areas and passages, in order that it may successfully cope with the very viscid substances it has to pump. While dealing with the general question of massecuite transporters, it will not be out of place at once to call more special attention to the elevators, which stand in conspicuous positions in Figs. 184 and 185. The general details of this class of transporter are seen in Fig. 188. The standpipes, in which the chains and disc-buckets work, are some four to six inches internal diameter, and are necessarily associated with the preparatory employment of a suitable form of pugmill, which reduces the

larger masses of solidified magma to such a consistency as will permit of its elevation by the apparatus in question.

In considering which of the above systems of dealing with the massecuite on its way from the pan to the centrifugals to adopt, a very important matter has to be borne in mind. Whatever, from a manufacturing point of view, may be the respective merits of this or that particular system, there is no doubt that the smaller and more numerous the massecuite receptacles, the greater must become the danger of loss due to waste and general un-

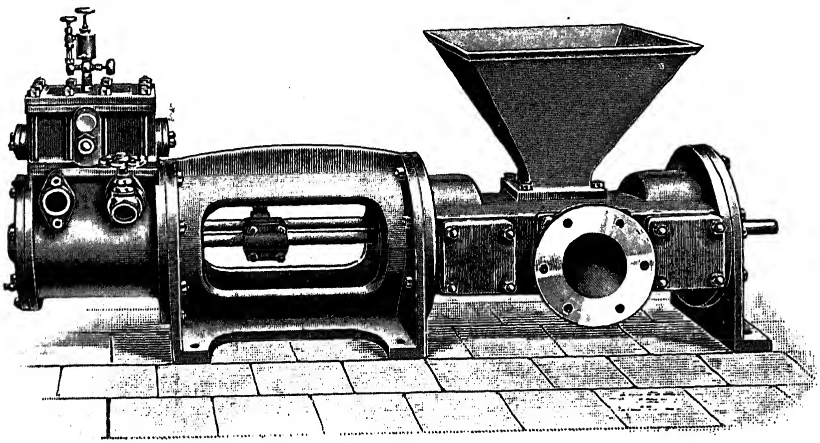

FIG. 187.—Steam-driven massecuite pump.

cleanliness caused by the increased quantities of wet sugar which are almost certain to be spilt on the factory floor. Increased labour and extra and special arrangements and supervision are involved if these drawbacks are to be combated successfully. The subsequent swelling of the massecuite, which frequently takes place whilst it is standing in the numerous tanks and boxes, has to be reckoned with, and the possible waste due to transport from place to place cannot be altogether ignored. Thus, other considerations being equal, there is much to be said in favour of the various

automatic arrangements of massecuite installations offered for the use of sugar-makers, which eliminate these annoyances and losses, and reduce the necessity for hand labour to the lowest possible point. About the most convenient and cleanest method of conveying massecuite from

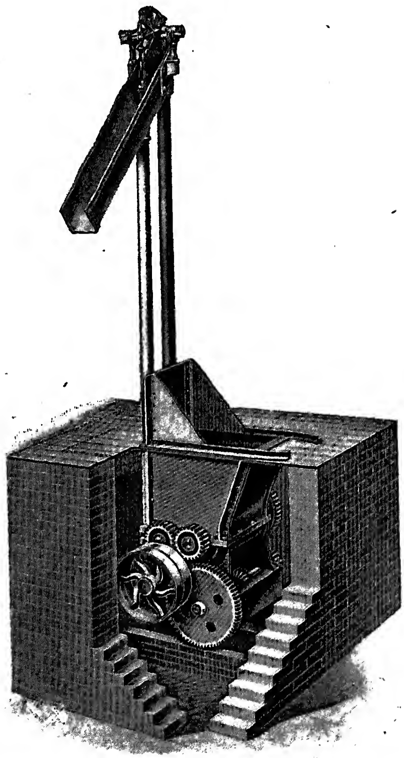

FIG. 188.—Chain and disc-bucket elevator, with attached sugar-breaker for treating stiff massecuites.

point to point in any factory is to effect its transportation through pipes of ample area by means of compressed air. It is perhaps surprising that, despite the many improvements made from time to time with regard to the above appliances, there are to-day to be found in existence some

of the oldest methods of handling massecuite, which are defended by their users as justifiable in the special circumstances of particular cases. As regards first products, one of the simplest ways of looking at this question is, in the first place, to divide the subject of sugar-curing in the centrifugals into hot curing and cold curing, and then select the

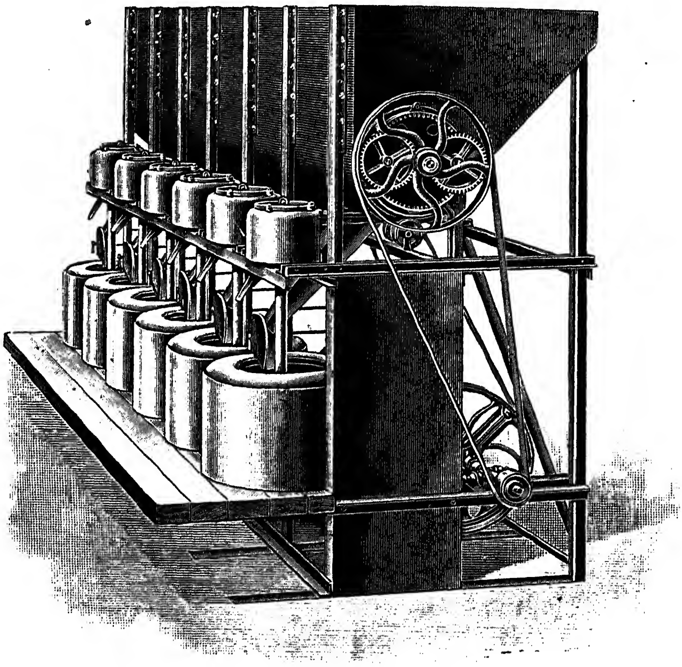

FIG. 189.—Centrifugals arranged for the "hot curing" of massecuite.

apparatus used between the pan and the centrifugals to suit the exigencies of particular cases, although in one sense it may be said that the majority of modern appliances are capable of being used for either system. In the case of hot curing, a process still in use in many factories, the massecuite is usually struck directly into a large receiver capable of taking the entire contents of the vacuum pan, such

receiver being placed immediately over the centrifugals (see Fig. 189). This vessel, fitted with stirrer gear, and commonly called a mixer, is attached to the framing of the centrifugals, so as to discharge through suitable valves into each centrifugal, and the contents of this mixer are spun off as rapidly as possible, so that it will be empty in time to take the next strike of the pan. On the other hand, in the case of cold curing the massecuite is allowed to stand for a longer or shorter period in one or other of the forms of tank described above, after which it is taken to the pugmills to be prepared for treatment in the centrifugals.

CHAPTER IX

THE PURGATION OF THE SUGAR CRYSTALS

THE final stage of the complete process of sugar-making proper, from the cane-mill to the sugar store, has now been reached. The sugar crystals have been formed, and it simply remains to separate them from the mother liquor, or uncrystallised syrup, with which they are closely mixed up in a mass or magma termed massecuite, in order that the crystals themselves may be placed upon the market in a suitable form. Such separation, or operation, known as "sugar-curing," is, in the case of the great majority of sugars, almost invariably effected by centrifugal force, and the machine in which this division is performed is known as a centrifugal. This mechanical agent has already appeared in the four illustrations Figs. 179, 183, 185, and 189, and a general idea will have thus already been gained of its outward appearance and its precise relative position with reference to the crystallisation machinery. It will not be possible within the limits of this work to attempt to do anything like full justice to the great care and ingenuity which have been exercised during very many years in perfecting the design and construction of the well-known sugar centrifugal. In order thoroughly to appreciate the many convenient forms in which this highly efficient apparatus is placed before sugar manufacturers, and the various mechanical refinements which have been introduced, it is almost indispensable to peruse carefully the elaborate catalogues and pamphlets prepared and published by the

makers of this class of machinery—publications which in many respects may be regarded as technical treatises on its construction and employment. The elementary principles upon which it is constructed and worked will be explained, and the facilities which may be assured by the employment of one or other of the various methods available for driving these machines described.

Each centrifugal, in whatever form it may appear, primarily and essentially consists of a cylindrical basket

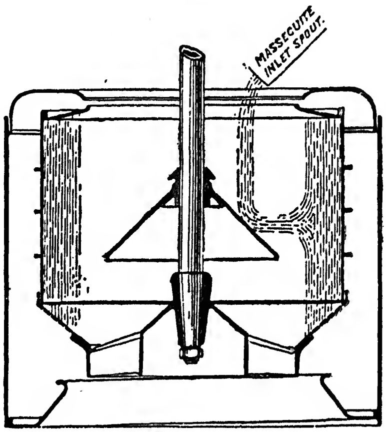

Fig. 190.—Section of a self-discharging centrifugal basket, with feed-distributing plate and valveless annular discharge opening, through which the dried sugar falls when the machine stops.

which revolves at a very high speed, and Fig. 190 serves to show how the massecuite is introduced into this basket for treatment. It also indicates the position it takes up against the sides of the basket, such attitude being due to the centrifugal force established and maintained by the rapid revolution of the latter. The entire circumference of the basket shell is perforated with numerous small holes, which are protected by an arrangement of "linings" placed against its inner surface. Reckoning from the exterior of the machine towards the contained massecuite, there is

first the perforated shell of the basket itself, then one, and sometimes two, layers of coarse iron or brass plain woven lining, then a layer of fine twilled or spiral woven brass lining, and, lastly, the massecuite or substance to be treated, which lies against the inner surface of the latter.

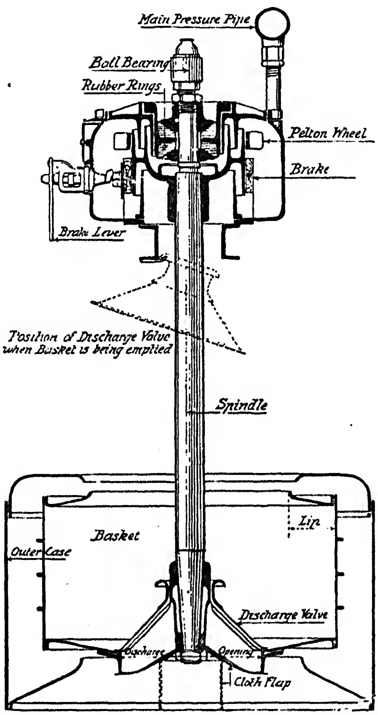

FIG. 191.—Section of a water-driven sugar-drying centrifugal, with Pelton wheel and ordinary discharge valve.

The intention of the finest and innermost lining is to prevent the sugar crystals from escaping along with the mother liquor which is being driven off, while the corresponding intention of the outer and coarser linings is to keep open the way of escape for the molasses, which ultimately passes through the very numerous holes in the basket, and is caught in the strong wrought-iron outer casing which com-

pletely surrounds and encloses it. Thus the sugar crystals are left behind in the centrifugal, and the molasses is led away from the outer casing to be made further use of according to circumstances. The centrifugal is now stopped, and the dried sugar falls through the bottom of the basket and is led away to the sugar store by means of conveyers.

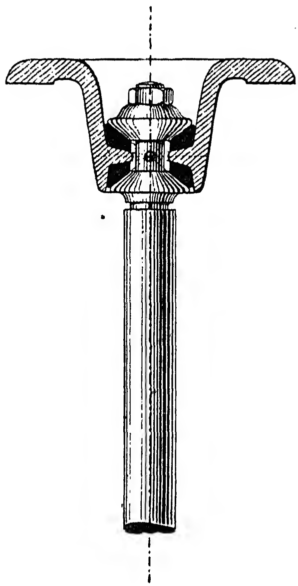

FIG. 192.—Sectional view of one method of suspending centrifugals fitted with fixed internal and hollow outer revolving spindles.

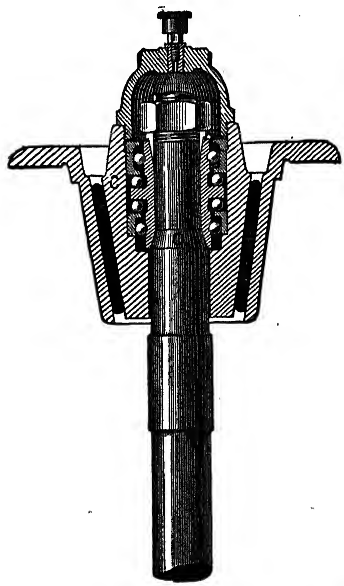

FIG. 193.—Sectional view of improved method of suspending centrifugals fitted with solid revolving spindles.

In Fig. 191 a complete section is shown of a water-driven centrifugal. Here the basket, with its sugar discharge valve, is seen to be suspended as usual within its outer case. The basket itself is secured to the lower end of the spindle hanging from a special form of bracket, which permits the machine to be self-balancing. Water, under high pressure, acting upon the vanes of the Pelton or

turbine wheel attached to the upper end of the machine spindle, causes both spindle and basket to revolve, while a brake is installed, just below the motor, for the purpose of bringing the machine to rest as soon as the sugar has been sufficiently dried. Various methods of suspension are adopted. In some cases a fixed internal spindle is held by two circular india-rubber buffers, as in Fig. 192. Around this stationary pivot, an outer hollow spindle revolves and carries the basket and its load of sugar. In other cases a spindle, solid throughout, is employed, suspended from a special arrangement of ball-bearings, as in Fig. 193. In whatever manner the suspension is effected, the chief object in view is to ensure the minimum amount of friction, coupled, within certain limits, with sufficient freedom to allow the spindle and basket to balance themselves when under the influence of unequal basket loads, and thus guard against any "pounding" of the machinery, with the consequently excessive wear and tear which would ensue at such high speeds, coupled with an unnecessary expenditure of driving power. With the same object in view, all revolving portions of this machinery are kept as light as possible and are most carefully balanced throughout. In Fig. 193 it will be noticed that a hollow conical rubber buffer-sleeve is employed to steady the spindle, in place of the disc buffers seen in the preceding illustration. As a result of these special methods of suspension, no heavy foundations whatever are required, and, when so desired, these centrifugals may be placed on an upper floor of the factory above the sugar store. Centrifugals may be driven in various ways, either by an engine and belt-driving arrangements of various kinds, as seen in Figs. 179, 183, and 185; or by a Pelton water-wheel for each separate machine, as already described in connection with Fig. 191; or by an electric motor which would simply take the place of the Pelton wheel.

Fig. 194 shows an installation of five centrifugals, three of which are worked with a belt-drive, and two of them by Pelton water-wheels. Had these two water-driven machines been actuated by electric motors, the general appearance of

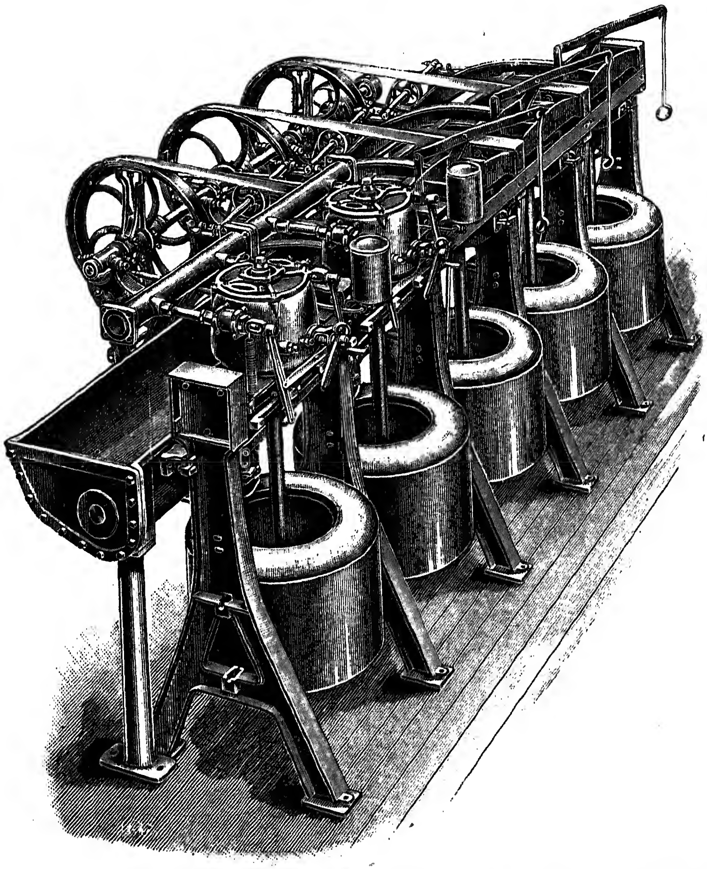

FIG. 194.—Combined arrangement of water-driven and belt-driven centrifugals, showing how the former are added to the latter, and contrasting the salient features of the two different methods of propelling the machines.

the installation would still have remained very similar with regard to the general features portrayed in the picture, which contrasts the two systems of driving employed in the same range of machines. When a belt-drive is used, the

machines are invariably placed, as shown, side by side in a straight row; and such a disposition of the component parts of the installation is essential, in order that they may fall into line with the counter-shafting. But when water or electric motors are adopted, a greater latitude is permissible in the arrangement when desired, and Fig. 195 shows an installation of six water-driven machines arranged in a circle, an arrangement which is not possible with the use of

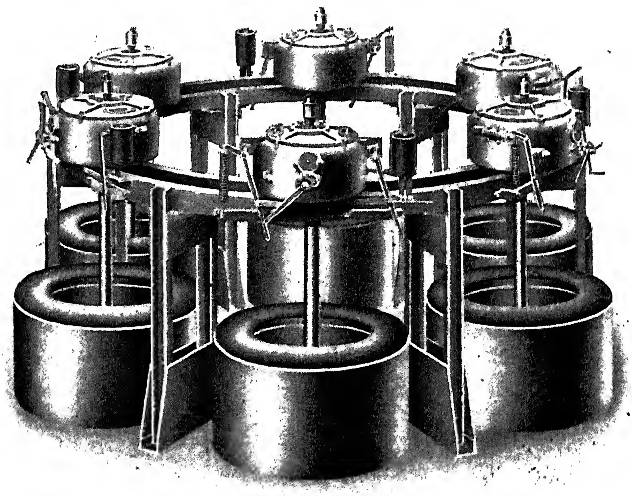

FIG. 195.—Six water-driven centrifugal machines arranged in a circle.

a belt-drive. In such a case the centrifugals would have to be placed in an elevated position, so as to deliver the sugar direct into the sugar store, or into a receiver common to all the machines, from which the crystals are removed by the usual elevator or conveyer.

Fig. 196 shows one method of driving a centrifugal by means of an electric motor, and, whatever differences may be introduced as to details of construction, and minutiæ of arrangement, certain important points have at all times to

be borne in mind when introducing this system of propulsion. In the first place, the motor has to be placed aloft, and out of the way of the attendants, where it cannot be splashed by the molasses and washing liquids. It is also preferable for the motor to be a fixture, instead of oscillating

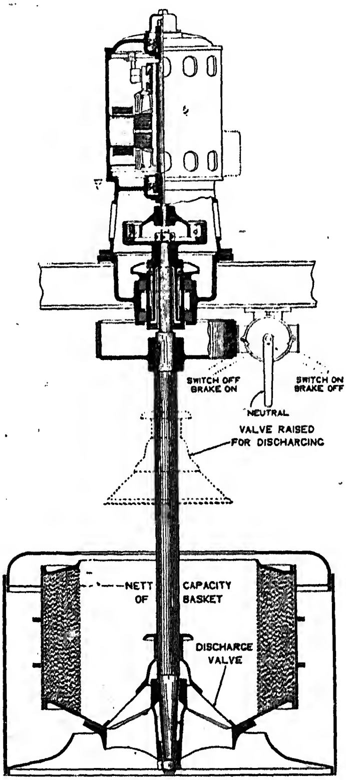

Fig. 196.—Section of an electrically-driven centrifugal, with fixed electro-motor attached to the upper end of the machine spindle.

with the centrifugal, and it is therefore placed above the machine framing and firmly attached to it. In such case it is independent of the centrifugal, and, not being affected by the oscillation of the latter, it is more conveniently designed to meet the requirements which the best electrical practice

demands. The centrifugal itself is as simple as an ordinary belt or water-driven machine, hanging on a rubber buffer in precisely the same manner, the upper end of the spindle, however, being modified to permit of a suitable connection to the motor through the agency of a specially designed friction clutch. Thus the motor may more rapidly attain its maximum speed, the centrifugal following and more gradually accelerating its speed until both the motor and the centrifugal are running at the same pace, so dispensing with the necessity for the use of artificial resistance when the motor is first started. This action is precisely similar to that of the original and standard centrifugal friction pulley, which, as is already well known, protects the belt from sudden shock when belt-driven machines are employed (see Fig. 185). Although the motor is generally fixed to the framing, it may nevertheless be constructed in such a manner that it can be promptly disconnected from the centrifugal, and access can be obtained to the spindle and buffer without disturbing any of the electrical connections. By these means a combination of an electro-motor and centrifugal is established on sound mechanical principles, combining simplicity of construction with ready access to all working parts, and affording the possibility of the employment of either a continuous or alternating current. This principle of a fixed motor has also been recently applied to water-driven centrifugals, coupled with a special form of interlocking gear, which regulates the manipulation of a range of machines (see Figs. 197 and 198).

The motor case 3—4 rests on the beams 40, which form part of the framing, and is fitted with a cover 1, into the centre of which is secured a hollow steel axle 9. This axle does not revolve. On the lower end of the axle a ball bearing 10 is placed; the inner part of the ball bearing is held firmly to the hollow axle 9 by the nut 12, and the

outer part 10 is held in the eye of the water wheel 2 secured by the nut 11, and revolves with the water wheel 2. The

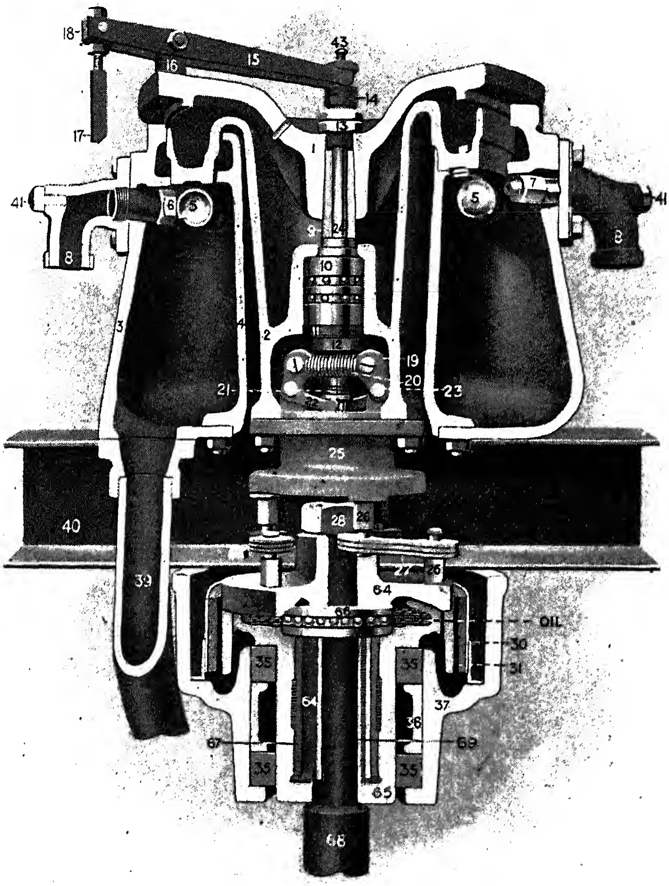

FIG. 197.—Fixed motor for water-driven centrifugals.

upper parts of the motor case 3—4 have flanges projecting towards each other forming diaphragms to prevent the water spray from getting over the top, so that there is no

possibility of the spent water going anywhere except through the return water pipe 39, back to the water tank which supplies the pump for driving the machines.

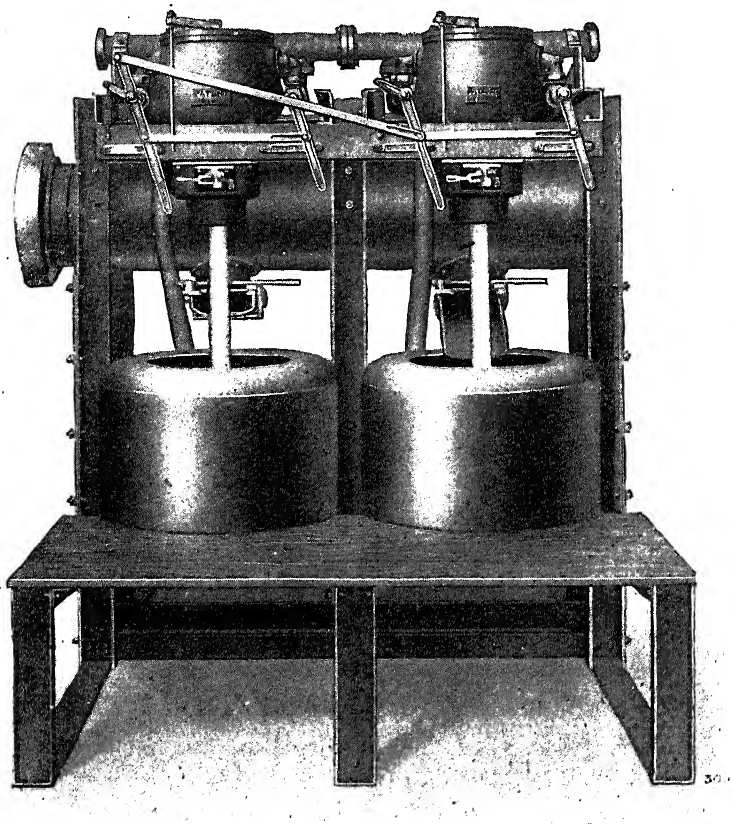

FIG. 198.—Two water-driven centrifugals, fitted with fixed motors and patent interlocking gear.

The top of the water wheel 2 revolves between the diaphragms on the top of the motor case, and on the face of the water wheel the water cups 5 are secured. The water cups 5 are fitted into a groove on the face of

the water wheel, so that the position of the cups can never be altered. The cups are of parabolic form, and properly relieved on the bottom side for the escape of the water when it has done its work. The cups are all carefully machined, and have knife edges so as to obtain the maximum efficiency from the water. As the water wheel does not oscillate, the water cups have always the same relative position to the water jets 6 and 7, and so maintain the highest efficiency.

The water jets 6 and 7 are screwed into the water inlets 8, into which are placed inspection plugs 41. In the event of the jets 6 and 7 becoming choked, the water inlet bends 8 can be removed, and the jets cleaned and replaced again in a few minutes without disturbing or undoing any other part of the machine.

On the bottom of the water wheel 2 is bolted the driver 25; this driver encloses the governor balls 19 in an oil-tight cavity below the ball bearing 10. This cavity is partly filled with oil through the oil cup 43, which lubricates the governor pins 23, the ball bearing 21 on the bottom of the governor spindle, and also the ball bearing 10. The governor spindle 24 is made in the form of a tube, through which the oil passes from the oil cup 43. On the bottom of the governor spindle 24 is fitted a ball bearing 21, and on the top a collar 14.

The governor balls 19 are held in the "off" position by the governor springs 20, which are made of such a strength that when the machine attains full speed the centrifugal force on the governor balls 19 causes them to fly outwards, and so move up the governor spindle 24 by means of the governor levers 22. On the top of the motor case cover 1 is fitted a fulcrum 16 for the governor levers 15. On the outer short end of the lever 15 a swivelling cross-head 18 is fitted, through which passes the governor

rod 17, which is adjusted and secured by two nuts. As already mentioned, when the machine attains full speed the governor spindle is moved upwards, and by means of the levers 15 the governor rod 17 is pressed downwards, which in turn releases the trigger rod 50 and so cuts off the water from the accelerating jet 6, leaving the smaller maintaining jet 7 in operation until it is desired to stop the machine.

To the underside of the beams 40 is attached the centrifugal suspending block 37, into which are fitted the india-rubber buffer rings 35, and which are separated by the loose cast-iron ring 36. It will therefore be seen that both top and bottom buffers support the whole weight of the centrifugal basket, which is attached to the lower end of the centrifugal spindle 68. This patented arrangement of buffers gives great resiliency and perfect steadiness of the machine when running with a balanced or unbalanced load, and as the buffers are separated by the loose iron ring 36, any wear on the bottom buffer is compensated by the compression, caused by the total load coming on to the bottom buffer, and so it is perfectly self-adjusting. Centrifugals are now fitted with the well-known ball and sleeve bearings as shown in Fig. 197. The combined brake pulley and driver 64 is fixed to the centrifugal spindle 68 by means of nut 28 and is extended downwards in the form of a sleeve also numbered 64; this sleeve revolves inside the gunmetal bush 67 and is the journal bearing of the centrifugal; the ball bearing 66 carries the weight of the revolving parts of centrifugal and also contents of basket.

The housing 65 fits inside the india-rubber buffers 35, and has a central tube 69 which extends upwards between spindle 68 and sleeve 64 and is clear of both; this central tube 69 forms an oil chamber in which the sleeve 64 and

ball bearing 66 revolve. The ball bearing and sleeve bearing are thus revolving in oil continually, so that there is neither wear nor friction. This bearing is very simple, requires no accurate fitting, and is very easily put together or dismantled.

The ball and sleeve bearing oil chamber is filled through the oil hole in top of combined brake pulley and sleeve driver 64.

To permit of the oscillation of the centrifugal spindle 68 and the basket, the water wheel 2, which does not oscillate, is connected to the brake pulley 64 on the top of the centrifugal spindle by leather links 27, the eyes of which are slipped over the points of the driving pins 26. It will thus be seen that the leather links 27 form a strong flexible coupling, which is simple and highly effective, and by slipping off the links the motor or the centrifugal can be detached when desired.

The brake band 30, it is important to note, is supported by angle-iron feet which rest on a flange in the suspending bracket 37, so that there is no possibility of the brake band drooping unequally. The feet on the brake band are also so arranged, that when the brake is off, an equal space is left all round between the brake band and the brake pulley 64.

By slipping off the connecting links 27, and taking out the four bolts which secure the suspending block 37 to the beams 40, the centrifugal may be removed without disturbing anything else. Again by removing the four bolts which secure the motor case to the top of the beams 40, and unscrewing the coupling nuts 53 which secure the inlet water valves to the bottom of the inlet water bends 8, the motor may be removed without disturbing the centrifugal machine or interfering with the working of any other machines in the range.

It is not within the scope of this work to attempt more than the foregoing delineation of the main features and principles of sugar-curing, and the account of those particular appliances which, all things considered, have shown themselves to be the most convenient and efficient. It is also unnecessary to do more than make a passing reference to the various sizes of centrifugal baskets which may be employed, or to the variations in speed requisite to suit the requirements of the different qualities of sugar manufactured, or to the use of cleansing water or steam which may be brought into play to hasten and perfect the action of centrifugal force. A more gradual acceleration of the centrifugals has to be enforced for lower class sugars than for the higher class; steam, as well as or in place of water, has at times to be applied to the massecuite under treatment, and large-sized baskets are frequently preferred to the smaller sizes, all these variations being dependent upon the special requirements of particular cases. In most tropical sugar factories the suspended and over-driven centrifugal is adopted, and a basket of some 30 inches is most generally employed, running at a speed of some 1200 revolutions per minute. It should, however, be noted that in Australia, Cuba, Hawaii, and Java, the 42-inch machines have been very largely used of late years, while the 48-inch machine is not unknown in the British West Indies. Although, for a given peripheral surface speed, the smaller machine gives a higher centrifugal force, and, on this score, has some advantage, the use of a larger centrifugal promotes labour economy; and due consideration must be given to these comparative factors before a decision is reached as to which size of basket is to be adopted.

In drying higher class sugars the bulk of the mother liquor is first driven off by the action of the centrifugal alone, and a preliminary stage is thus completed and a

point reached at which the work of the machine must be supplemented by the use of steam, water, or syrup, which is next passed through the mass of crystals spinning in the basket. This supplementary procedure is essential, for otherwise the crystals will suffer from the presence of molasses left adhering to their surfaces, and their colour will not be maintained at the requisite standard. These "washings," as distinct from the discarded mother liquor due to the first stage, are of superior quality, and in many of the leading sugar factories, especially where charcoal filters are used, it is deemed a matter of importance to keep them quite separate. This classification of syrups is best effected by what is termed "fractional" or "double curing," which is duly performed by such a double installation of centrifugals as is shown in Fig. 199. It will be seen that there are two distinct sets of machines, separated by a sugar elevator and overhead mixer. The massecuite from the vacuum pan is introduced into the first set of four machines, where the bulk of the mother liquor is removed. The partially cleansed crystals are now let out of the baskets into the conveyer located beneath them, which takes them to the elevator. This in turn deposits them in the mixer. They are then amalgamated with a superior class of washings obtained from sugars previously treated, thus re-forming a massecuite of higher syrup qualities than before. This re-formed massecuite is then re-centrifugalled in the second batch of five machines, where the sugar crystals are thoroughly washed and dried, and the syrup thus obtained is kept free from contamination with inferior products. At the same time, there is some uncertainty in adopting this system, for a particular quality of massecuite might require, say, four machines for the first battery and six for the second, while another class of massecuite might call for the use of equal batteries of five machines each, or

the best combination might even be found to be three and seven machines. This uncertainty has led to the use, in many cases, of centrifugals arranged in one battery, and provided with double charging troughs, double conveyers, and double molasses gutters, so that each respective centri-

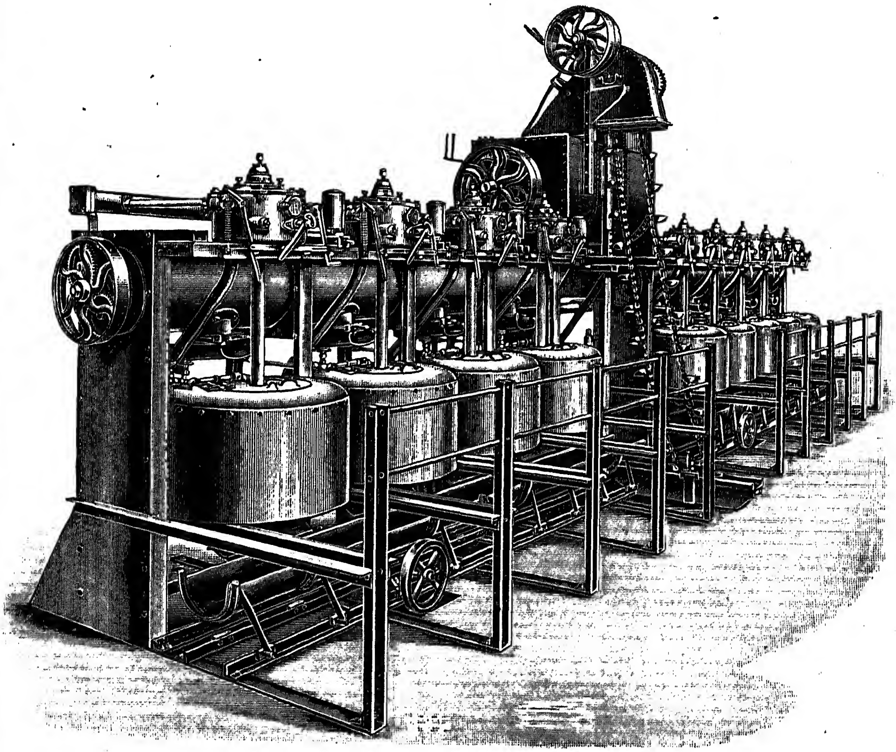

FIG. 199.—Combined double battery of centrifugals, as arranged for "fractional" sugar-curing and the classification of syrups.

fugal can be used in either the first or the second division at will. To the same end another arrangement of centrifugals is so carried out (see Fig. 200), that the sugar is first purged of its mother liquor in a large-sized centrifugal, which is made to discharge itself as soon as it stops. The

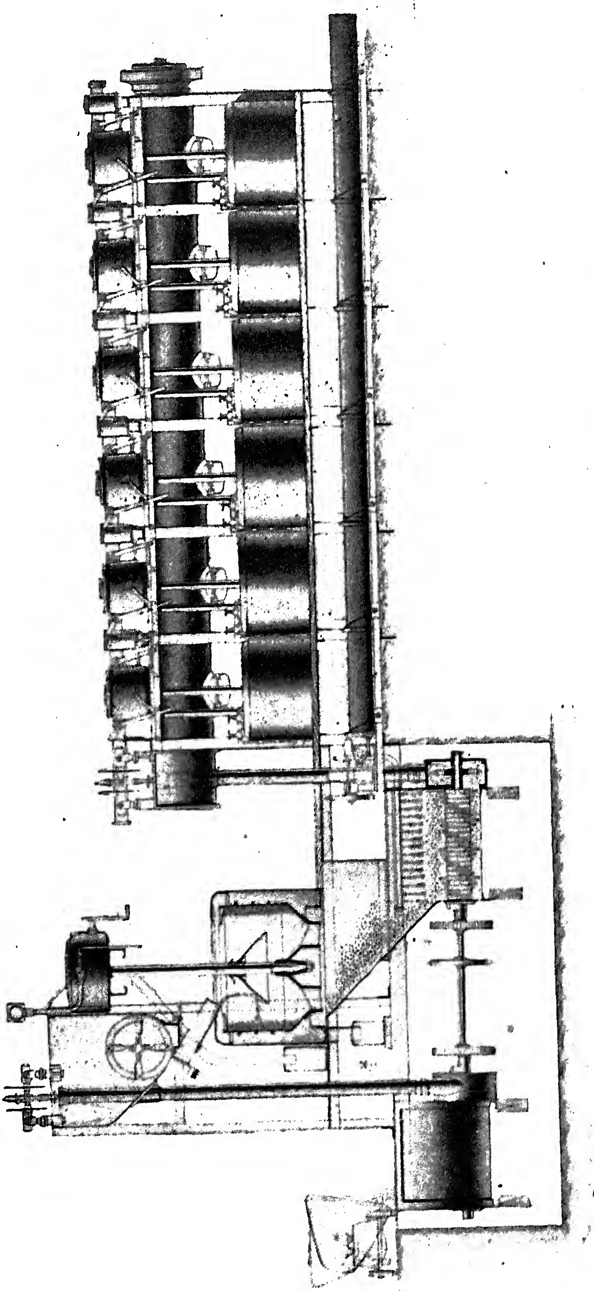

FIG. 200.—An alternative arrangement of centrifugals used for fractional sugar-curing.

capacity of this initial machine is enough to perform all the preliminary work to prepare enough massecuite for a considerable number of smaller and following washing centrifugals after the partially dried sugar has been prepared in the intermediate mixer.

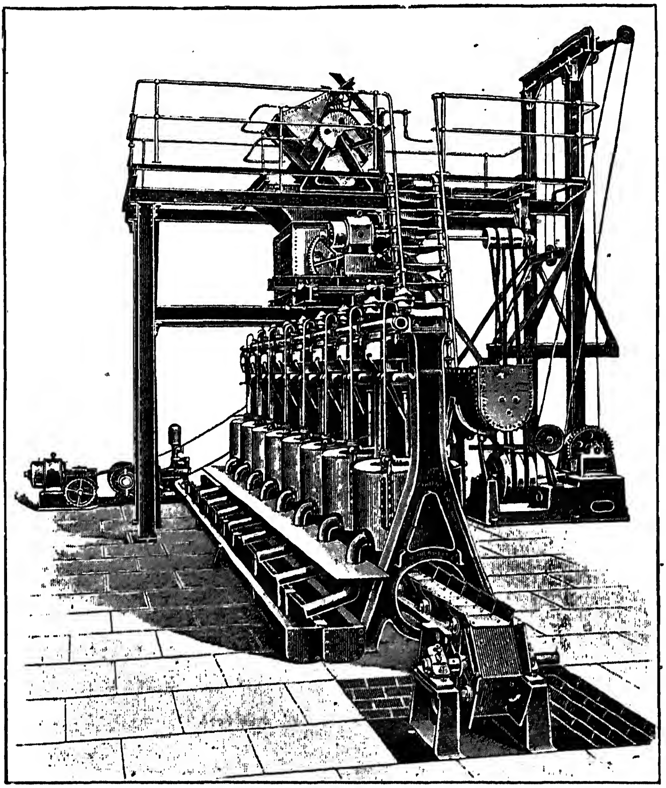

FIG. 201.—Complete arrangement of a battery of centrifugals fitted with massecuite and dry sugar handling appliances.

Belt, screw, grasshopper, and trough conveyers are used for the purpose of removing the dried sugar crystals from beneath the centrifugals, these being frequently assisted by the employment of chain and bucket elevators, which raise the finished product to the sugar store. In Fig. 201 a

trough conveyer is seen in use, and this illustration likewise shows a complete centrifugalling plant which is much used in Louisiana and Cuba. Here the lifting and emptying appliances for mechanically handling the massecuite in the first instance when it first reaches the centrifugals are delineated, together with the overhead receiver, pugmill, and mixer. The range of eight machines, driven, as preferred, by either water-pressure or electricity, are also shown, with their accompanying molasses spouts and troughs, and the dry sugar conveyer already alluded to. This illustration is a fitting conclusion to the description of the process of the purgation of the sugar crystals, emphasising as it does the efforts which are constantly and successfully being made to perfect this section of sugar manufacture and to render it as automatic and efficient as possible.

CHAPTER X

SCIENTIFIC CONTROL OF THE FACTORY

The scientific control of a colonial sugar factory should always be regarded as one of the chief functions in connection with the manufacture of cane sugar, and its increasing importance is gradually recognised by those connected with it. In the beet industry it rules supreme, a circumstance which is partly accounted for by the fact that this manufacture is prosecuted in districts which can command at their very doors the guidance and services of the ablest exponents of its scientific aspect, and partly because the process of manufacture renders accurate scientific supervision obligatory. Distance, which in past years has lent a somewhat treacherous enchantment to the disregard of many matters of vital moment to colonial factories, has rendered the attainment of a correspondingly efficient scientific control of cane-sugar manufacture an exceedingly difficult matter, and has retarded many praiseworthy attempts to establish it. But at the present day closer chemical and engineering attention is being paid to various points which in the past were judged empirically; and it is the object of this chapter to touch briefly upon a few details which are of paramount importance in the technical conduct of cane-sugar manufacture.

Not only is an accurate knowledge required of the quantity of sugar coming into the factory in the form of cane, with a *per contra* account of that sent out in the finished product, but figures showing as well the character

of the intermediate work have also to be recorded faithfully, in order that a finger may be at once placed on any cause which has led to loss in manufacture, with the view of removing it, if possible, or of reducing it to a minimum, if unavoidable. In this way the relation of the chemist to the work of a sugar factory may be likened to that of a book-keeper of a mercantile concern, only that the records are kept in terms of sugar, rum, and molasses, instead of pounds, shillings, and pence; while the accounts of each department are kept separate so that a correct balance-sheet may be struck not only of the work of the factory as a whole, but also of the various sections comprising it.

In such a balance-sheet, however, there is one point which constitutes a prominent difference between it and its mercantile prototype, and this is, that while in the latter the balance appears, or should appear, on the side of gain, the accounts of the factory chemist must invariably show a sugar loss, successful work appearing in the diminution of such loss, rather than in the realisation of profits.

It is a regrettable fact that up to a few years ago the full value of scientific records in connection with cane-sugar factories was not generally recognised by those in charge, the keen eye of the practical sugar manufacturer being considered to be all-sufficient to control the manufacture. In these days of keen competition, however, when a few points per cent. gained or lost may determine the question of profit or loss, it is recognised that closer supervision is required, and that the mere appearance of the megass filter-cake or massecuite is an inadequate check on the amount of sugar liable to be lost from faulty work. Similarly, the fine appearance of the furnace combustion, or the absence of steam leaks, although excellent indications in their way, are not sufficient guides in themselves to the fuel loss. An engine, for instance, may appear to be working quite

well and at the same time be wasting fuel from uneconomic setting of the slide-valve or other cause not apparent to the eye, but yet avoidable. As, however, this is not a scientific treatise, it is not proposed to give an account of the physical and chemical methods employed by the engineer and chemist in obtaining the desired information in their respective departments—methods which will have formed part of their scientific education—but rather to provide an idea of the data required to control satisfactorily the work of the factory.

In respect to staff, it is important that the engineering department should be sufficiently strong and adequately equipped, not only to be able to supervise the running of the machinery, but also to carry out the physical observations essential to its proper working; while the chemical staff should be so constituted as not only to be in a position to maintain the regular records, but also to undertake any special investigation arising from them.

The engineering staff of a colonial sugar factory is placed, in one respect, in a peculiarly favourable position for effective performance of its dutes in connection with the maintenance of the efficiency of the machinery placed in its charge. In the majority of sugar-growing countries it rarely happens that the factory is in actual operation for more than four or five months of each year, and the remaining portion is thus available for a thorough examination and overhaul of all mechanical details, and for the correction of all defects which may have revealed themselves during the work of the preceding crop. Moreover, favourable opportunities of considerable length annually present themselves for the erection of additional and improved appliances. Sugar-canes and cane juice are peculiarly perishable substances, and, once the canes are cut, the sooner they are crushed in the mills the better; and

once the juice is expressed, the sooner it is converted into sugar the more likely will be the attainment of satisfactory results. It is thus evident how important it is that there should be no breakdowns of the factory machinery to interrupt manufacturing operations during the entire campaign, and it is for the engineering staff to take every available precaution to ensure smooth and continuous work.

Careful and constant supervision of the machinery when at work during crop-time helps one to arrive at a judicious decision as to the necessary repairs which should be effected at the close of the crop, as well as to the additions of new and improved appliances which ought to be made during the recess. If at all possible, indicator diagrams are frequently taken of the working of all the engines throughout the factory, with the dual object in view of checking the correct setting of the various slide-valves and of ascertaining the actual amount of power expended in relation to the quantity of work done in each section of the manufacture. The crushing efficiency of the cane-mills is also continuously noted and associated with the expenditure of power in the cane-engines; and, on the score of fuel economy alone, the extraction is kept up to the most efficient point possible. Such preparatory procedure enables the engineer, amongst other things, to estimate approximately the amount of steam used up in the engines throughout the factory. He also endeavours to ascertain, as accurately as possible, the amount of steam absorbed in each of the numerous and varied forms of heaters and evaporators which deal with the cane juice; and he therefore carefully watches the details of the work of each section of the factory. He keeps himself informed as to the average density and temperature of the extracted cane juice issuing from the cane-mills, as well as its successive densities and temperatures for each section of the manufacture. These

ata, coupled with a knowledge of the average weight of anes, megass, and juice dealt with per hour, enables him, t the close of the crop, to account for the proportional xpenditure of fuel, which should have been carefully veighed throughout the campaign. A large proportion of hese general details are identical with those required for he sufficient chemical supervision of the manufacture roper; and, to this extent, the interests of both chemist nd engineer are identical, and the recorded observations of he former are of invaluable assistance to the latter.

By means of the information gained in this manner, a airly accurate balance-sheet can be made out at the close f the crop, which is of great assistance in determining how he steam has been used up in each section of the sugar actory, and enables a finger to be placed upon flagrant auses of waste of fuel. For instance, apart from the uantity of steam required for the purposes of evaporation, t is remarkable how much is frequently absorbed in simply aising, maintaining, and restoring the juice to comparatively low temperatures. This emphasises, other hings being equal, the great importance of rapidity of nanufacture, and the desirability, once the juice is heated, of not permitting it to hang about and cool unnecessarily between the successive stages of manufacture.

The fuel question of a colonial sugar factory is one which asserts itself with peculiar prominence, from the fact that the steam is raised through the agency of various kinds of fuel obtained from divers sources. Unless the megass is made to do the entire work of the factory, the balance of the fuel account has to be made up of either coal, wood, bamboo, cane-trash, or even molasses. The use of fuel from outside sources should be discouraged, the megass produced from the canes by the mills being utilised to its fullest extent. It is an unavoidable and necessary product

of the process of juice-extraction, and, except for the comparatively trifling cost of its removal from the mills and its subsequent distribution to the boiler furnaces, it is handed over to the engineer, as it were, free of cost, to be made the most of, and to be utilised as the leading source of power, or steam, that is required in the factory. The less desirable source, and one which is curtailed to the utmost extent possible, is imported coal, which by reason of the great distance over which it has invariably been conveyed to the scene of action, is very expensive. It is also very regrettable to consume any of the cane-trash in the boiler furnaces, the proper disposal of this dried cane foliage being a carefully controlled return to the soil of the field whence it came. In well-ascertained cases in which effective boiler and furnace improvements have been carried out, resulting in the use of megass alone as fuel, a marked improvement in the field crops has been attained, such improvement being undoubtedly due to no other cause than the rational return of the cane-trash to the land, in place of its improper destruction in the factory furnaces.

Much depends upon the composition of the canes, the efficiency of the extraction, and the extent to which the normal cane juice is diluted by the practice of maceration at the cane-mills, as to how much outside fuel has to be burnt; but in well-arranged factories, fitted with the most modern appliances, it is possible to work the entire factory with megass fuel alone, and, notwithstanding numerous variations in the method of manufacture which may obtain in different factories, thus avoid the use of extraneous fuels. In all cases every effort is made to reduce the coal bill to the lowest possible figure, and therefore the engineer pays the closest attention to the design and construction of the megass furnaces, and, in conjunction with the chemist, to their proper working.

These furnaces, as will presently be shown, are of very special design, offering scope for unremitting efforts in the direction of the attainment of the best results. Frequent megass analyses and boiler tests are conducted, so that the amount of steam supplied to the factory may be ascertained as accurately as circumstances will permit, and these at the same time furnish a record of the efficiency of both fuel and furnaces.

The importance of the question of an efficient control of the steam consumption in any given factory cannot be exaggerated. It is not too much to say that in a well-arranged and properly controlled factory, and with canes containing not less than 10 per cent. fibre, no fuel of any kind whatever, other than megass, should be required, save, possibly, at the very commencement and conclusion of the crop. This statement is confirmed by practical experience, and is further supported by such theoretical calculations as have been made from time to time. In fact, such calculations tend towards the establishment of the assertion that, theoretically, the megass from any given quantity of average canes should furnish an abundance of fuel for the conversion of the resultant juice from such canes into sugar. Furthermore, it must not be forgotten that it is unreasonable to expect to burn widely differing fuels in one and the same class of furnace, and nevertheless attain maximum efficiency. Hence the desirability of retaining megass furnaces solely for the consumption of megass. Again, it must not be forgotten that a given amount of megass can only be expected to generate a certain quantity of steam, and the primary point in boiler-house control is to ensure the generation of this full quantity.

The second point, after having thus secured the maximum supply of this indispensable agent, is to control

its distribution and employment in the most careful and judicious manner possible. The prevention of mechanical waste by way of steam-leaks and defective engine-valves has already been noted, and must not on any account be neglected. But there is much else that may be effected by the correct application and use of steam throughout the major portion of the factory operations. Maximum employment of the multiple effect is imperative, together with an efficient use of the juice heaters that ought to be attached to this apparatus and worked as an integral part of it. The latter should be invariably used towards heating the juice coming from the mills, the earliest application of such heating having been effected at the very outset by a large heater worked by the waste vapours from the effect and vacuum pans (see Chapter VII.).

The juice-heaters worked by exhaust-steam from the various engines throughout the factory next claim close attention both as to design and working efficiency. Then the clarifiers or defecators should receive unremitting attention both as regards their general design and the maintenance in first-class working order of their heating-surface arrangements, and all the more so inasmuch as they have by preference frequently to be worked by the use of direct high-pressure steam. In such case this direct steam should only have to be supplied to each clarifier or defecator for the space of about one minute, and, if all preliminary arrangements have been satisfactorily established, this brief application of direct steam can be secured (see Chapter V.).

The vacuum pans require constant supervision, more especially in factories in which the pan-power is somewhat in excess of actual requirements. They are proverbial steam-eaters, more especially during the earlier stages of crystallisation, and will often draw considerable quantities

of high-pressure steam direct from the boilers at moments when it can ill be spared. They should never be allowed to use direct steam *ad libitum* according to the uncontrolled will of the pan-boilers, and it is not so much the necessary total steam consumption per day, if uniformly drawn, that is objectionable, but the irregular drafts of excessive amount that are spasmodically withdrawn, in the absence of the necessary control, that disorganises the steam supply of the factory; and it is not an extreme statement to say that, if due control is maintained in the prevention of these spasmodic drafts and, in their stead, a uniform and more continuous draft is ensured, then, in the case of many vacuum-pan installations, the main steam-pipe, supplying the same with direct steam, might in many cases be reduced 75 per cent. in area without entailing the slightest uncalled-for inconvenience in the due performance of the full day's work. A "feeder" vacuum pan, worked by exhaust-steam, can be employed for the earlier stages of crystallisation, preparatory to the subsequent use of pans worked by direct steam, and the massecuite of low densities would be passed on from it, by suction pipes, to the finishing pans.

Careful attention is paid to the quality and quantity of lubricants employed throughout the factory, more especially with reference to the lubrication of the engine pistons and slide-valves. In a sugar factory, where so much exhaust-steam is used in heaters and evaporators of all descriptions, the water of condensation from which is returned to the boilers, there is great danger of fouling the boiler feed-water supply when excessive quantities of oil are used in the engine cylinders. Moreover, no door is more readily opened to a penny wise and pound foolish policy than by the application of inferior and unsuitable qualities of lubricants to the various machinery journals, the centrifugals especially

calling for precise treatment in this respect. With further reference to the possible fouling of the boiler feed-water, a careful watch has to be maintained in the direction of juice leakages which may permit "sweets" to find an entrance into the steam spaces of the heaters and evaporators, whence they would pass to the boilers along with the water of condensation.

At the close of the crop ample opportunity presents itself of effecting the necessary repairs and alterations suggested by experience during manufacture. All engine pistons and slide-valves are opened out, cleaned, examined, repaired, and carefully replaced and readjusted. All the steam boilers are cleaned and inspected, the furnaces at the same time being thoroughly overhauled. All general foundry repairs are arranged for and executed, while the machinery as a whole is opened out and examined wherever there is any suspicion of inefficiency. Delicate portions such as the centrifugals require special attention and treatment, and the oil in them should not be left within the spindles or ball-bearings to clog and cause trouble at the beginning of the following campaign. The evaporators and heaters are, of course, thoroughly cleansed and hydraulically tested, as any neglect in this direction, especially in connection with the multiple evaporators, has prejudicial effects on the fuel account. So, too, any juice leakages, as already observed, adversely affect the boilers. General cleanliness throughout each group of heating surface is very important, as having a special bearing upon the greater or lesser steam pressure which may have to be used in conjunction with them. In a sugar factory unique opportunities are afforded for utilising the exhaust-steam from the engines, and well-cleaned heating surfaces enable this advantage to be made the most of without throwing an excessive back pressure upon the engine pistons.

Few industries, indeed, offer such satisfactory scope for ascertaining, step by step, the results corresponding to the application of a given amount of steam throughout the component sections of the complete process. The sugar estate engineer has thus a field of observation before him which is second to none from the point of view of general interest.

The chemical control centres primarily around the accurate recording of the quantity of sugar which comes into the factory in the form of cane. This is the most difficult item in the factory records to obtain an accurate account of. The variation in the sugar content of canes is enormous. Not only do canes from the same field show different sugar contents, but variation also occurs throughout the length of the cane itself. Plants and ratoons cut at the same time will vary considerably in their sugar richness, while the same may be said as regards the different varieties which now, to so great an extent, make up the cultivation of a tropical sugar estate. Accurate sampling of the cane, therefore, for the purpose of chemical analysis is impossible in practice, and figures referred to the whole amount of canes ground based on analyses conducted on samples must, therefore, be looked upon as being merely approximations. Formulæ, by which the sugar content of the cane is calculated, founded on various analytical results, must also be placed in the same category. Megass, however, affords a better field for accurate analytical results, and as the weight of this is given, sufficiently near for all practical purposes, by the difference between the weights of cane ground and that of the juice expressed, the total amount of sucrose or cane sugar in it is obtainable. This, when added to the amount in the juice expressed, gives the total quantity of sugar in the canes ground, the actual weight of the latter being directly obtained by

weighing the carts or trucks containing them on platform scales before being discharged at the mills. It is important, however, that the analysis is put in hand as soon as possible after the taking of the sample, as evaporation proceeds rapidly.

When, however, maceration is employed, the conditions become more complicated. In this case, it is essential that the total quantity of maceration water be known, otherwise the weight of the megass cannot be found by this method. The amount in the juice can, it is true, be calculated by comparing the specific gravity of the first mill juice with that of the diluted juice. This method, however, assumes that the juice expressed by the first mill is of the same density as the undiluted juice from the last mill, an assumption which is not correct. Even if this method of determining the amount of added water in the juice were correct, no clue would be given to the amount of maceration water which has found its way into the megass. There is, however, no difficulty in accurately gauging the quantity of maceration water used, and this should be done. It may, indeed, be taken as a golden rule in factory control to take direct figures when it is possible to do so, rather than to trust to the fascinating, although frequently misleading, methods involving the use of formulæ based on purely laboratory results.

The weight of maceration water being thus known, the weight of megass is readily obtained. If W = weight of cane, W_1 = weight of maceration juice, W_2 = weight of maceration megass, and M = weight of maceration water,

$$W_2 = W + M - W_1.$$

The weight of macerated megass being thus known, with its sugar content, the weight of sugar going to the furnaces can be ascertained, which, added to that in the juice expressed, gives the quantity of sugar coming into

tory, and, by comparison with the weight of cane, centage of sugar in the latter.

ther details as to the composition of the juice and beyond the mere expression of the amount of present are also essential. The amount of unisable sugar and the percentage of impurities—the ound by taking the Brix, or Balling, density or the ion of the refractometer as indicating the total solid of the juice—are also valuable items of information of view of the working characteristics of the juice. ledge of the proportion of water and fibre in the is also a useful check on the work of the mills.

ugar-growing countries where the canes are transto the mills by waterways, considerable difficulty ascertaining the weight of cane ground. A loadthe punts, apart from its want of delicacy, is inacinasmuch as its indications are liable to be affected age or rainfall, while to lift out of the water and he entire punt and contents is outside the region tical methods. In such cases the best solution of olem is to weigh the megass. This is done either by ging the megass into trucks as it comes from the and passing these trucks over platform scales on to the furnaces, or by the use of an automatic in which the megass can be weighed while on a al carrier.

an old-established and common practice to express k done by mills by the percentage of "crushing" l, *i.e.* by the percentage of juice extracted. Unless ression is taken in conjunction with the amount in the cane, the figure obtained is worthless as an the quality—*i.e.* the proportion of sugar extracted resent in the canes—of the work done by the mills. res also, in order to correct the quantity of juice

obtained for the amount of water contained in it in the form of maceration water, recourse to laboratory figures of density in which very slight observation differences may lead to considerable error in the calculated results, apart from other causes of error already pointed out. The most reliable method of indicating mill work is to take the relation of the total amount of sucrose present in the juice expressed to that in the canes ground. Thus, if this figure, with an eleven-roll mill plant and with the use of 20 per cent. maceration, amounts to 92 per cent., the quality of the work of the mills would be looked upon as good. The "crushing" figure expressed in the old way might be anything between 72 and 80 per cent., according to the proportion of fibre in the cane, and comparisons based on this figure are proportionately misleading if the latter factor is not considered. The percentage of sugar extracted, however, at once gives an accurate indication of the character of the work done, although an extreme proportion of fibre still modifies to a small extent the inference to be drawn from the percentage of sugar obtained.

The water content of the megass is frequently considered as affording a reliable index of the work done by mills in the direction of the extraction of sugar. Here, again, without a knowledge of the amount of fibre present in the cane, the figure is valueless for this purpose. The mere statement that a mill has reduced the percentage of water in megass to this or that figure conveys little or no information as to the quality of the work done. The fallacy of the theory upon which this practice is based is easily shown. Thus, taking the case in which canes of 11 and 14 per cent. fibre respectively supply a megass of a uniform water content, say 50 per cent. (no maceration water being used), with juice of the same density, say 17 Brix, the composition of the canes will be:—

	I.		II.	
Fibre	—	11	—	14
Juice—				
Solids	15·1		14·6	
Water	73·9	89	71·4	86
		100		100

The megass in each case would have the following composition:—

Fibre		39·8
Juice—		
Solids	10·2	
Water	50·0	60·2
		100·0

and the distribution of the cane between the juice and megass would be:—

	I.		II.	
Megass—				
Fibre	11·0		14·0	
Juice	16·63		21·18	
		27·63		35·18
Expressed juice		72·37		64·82
		100·00		100·00

and the weight of juice extracted from the cane 81·3 and 75·4 per cent. respectively.

A further example of the errors which may arise from the use of a formula alone is given by a method of expressing the quality of the mill work, based on the proportion of sugar in the megass calculated as first mill juice, to 100 parts of fibre present, which has recently been devised. The formula is—

$$\frac{\dfrac{\text{Per cent. sucrose in megass}}{\text{Per cent. sucrose in first mill juice}} \times 100}{\text{Per cent. fibre in megass}} \times 100$$

This is open to a similar objection to that in the previous instance, viz. that unless the canes of which the mill work is composed contain the same proportion of fibre, no correct inference as to the amount of sugar extracted can be drawn. As there shown, megass from canes carrying different percentages of fibre, but juice of the same strength, may mean different sugar extraction. Such a megass would give identical figures in both instances by the use of the above formula, although, as has been shown, different percentages of juice, and consequently sugar, would have been extracted. Such methods of comparison are therefore useless, *per se*, as guides to extraction of sugar, unless other indications of the amount of work done by the mills are considered in conjunction with them.

The question of the percentage of sugar extracted by a milling plant is not the only one which arises in this connection. Quantity—*i.e.* the tonnage of canes dealt with—as well as quality requires to be taken into consideration before a satisfactory conclusion can be arrived at. Another important feature is the amount of maceration done. A considerable degree of sugar extraction may have been arrived at by its means, while the proportion of water in the megass remains the same, or is even greater than it would be if no maceration water had been employed. Any statement, therefore, regarding mill work should include the tonnage of canes ground per hour, percentage of fibre in canes, percentage of sugar extracted on that in cane, and the proportion of maceration water used.

A further item of importance is the indicated horsepower developed by the engine or engines for the work done, while, in addition to the above, the description of canes ground is mentioned. For, quite apart from the proportion of fibre present, the physical condition of the rind characteristic of the variety of cane dealt with affects the

feed capacity of a mill considerably, although the modern use of preliminary crushers has had the effect of eliminating to some extent this factor in milling.

The records of mill work being thus provided for, the next step is to obtain the necessary data for the calculations referring to the working of the juice—and the basis is given by the quantity of sugar recorded as having come into the boiling-house in the form of juice. For this purpose an accurate record of the juice delivered is essential. The ordinary method employed, where the juice heater and subsiding tank system is adopted, is to measure either the cold juice before liming and heating in gauged tanks, or the hot juice in the clarifiers, in the latter case a correction for expansion being made according to the temperature at which the measurement is taken. This correction for practical purposes may be taken as being 3·5 per cent. at 200° Fahr., 3 per cent. at 190° Fahr., and 2·25 per cent. at 180° Fahr.

If the system of clarifier measurement be adopted, the polarisation of the juice at this stage can be taken as a reliable basis for calculating the amount of sugar extracted by the mills. If, however, the juice is "sulphured" prior to passing through the juice heater, it is necessary to polarise the cold juice, as inversion, with consequent destruction of sugar, may have taken place therein. Great care in this case is requisite in sampling the juice, so as to obtain representative samples. Where the French defecator system of clarification is used, tanks have to be provided for measuring the cold juice as it comes from the mill.

In some instances automatic juice weighing-machines based on the revolving drum system are in use, as seen in Fig. 202. A drum, *c*, divided into compartments, and suspended from one end of a steel weighing yard, is supplied with juice from a tank, *a*. In this machine one compart-

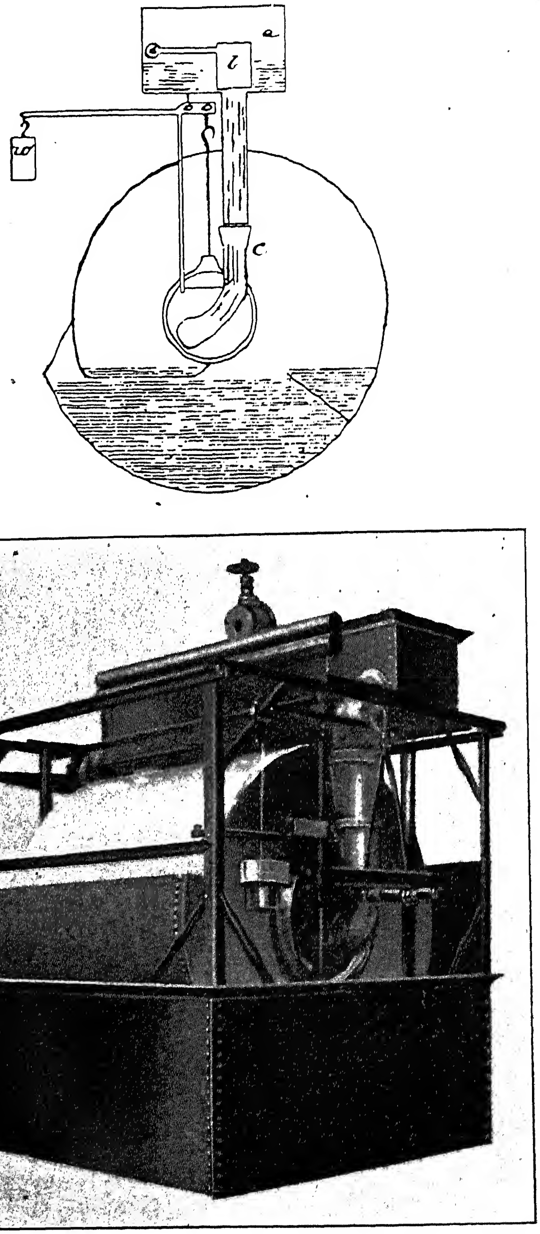

FIG. 202.—Automatic juice weighing-machine on the revolving drum system.

ment is being filled while another is emptying. When a balance is obtained between the drum and its contents and the counterweight, *w*, the flow of juice is automatically directed into the succeeding compartment. As the latter fills, the previously weighed juice is discharged.

A convenient form of juice meter is also afforded by the apparatus shown in Fig. 203. It is actuated by weight

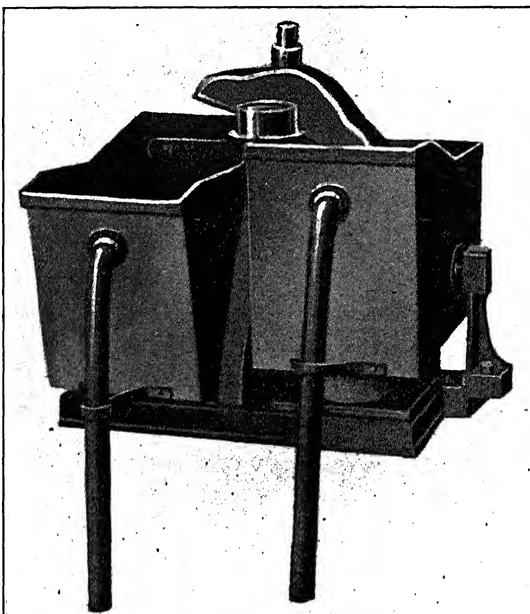

FIG. 203.—Another form of automatic juice meter.

and not by volume, and is not affected by grit and impurities. It is extremely simple, and can be readily cleaned and sterilised. The meter (Fig. 204) consists of two tanks of equal size (see A^1 and A^2) which work on edged prisms, B, around axles dividing the tanks into two unequal parts. Each tank is fitted at one end with a syphon pipe, C, and at the other with weights, D. The liquid to be measured flows through the pipe E, passing along the gutter F, into

either tank. The weights D are so adjusted, that until the tanks are filled with the liquid up to the height marked G, they remain in a horizontal position; but as the liquid rises above that point by the continued flow, the tanks come into the position as shown by the dotted lines, when the

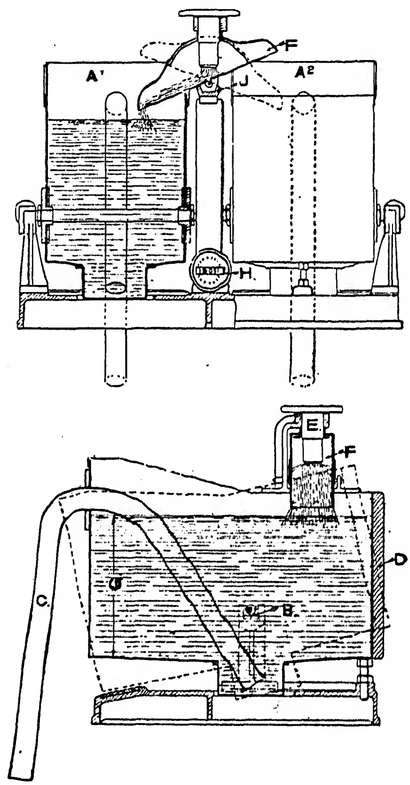

FIG. 204.—Sections of juice meter shown in Fig. 203.

liquid flows through the syphon pipe. After the syphon has been started, and the level of the liquid in the tank has fallen sufficiently, the tank tilts back again to its original position, by the influence of the weight D, the syphon continuing in action until the tank is emptied. As each tank assumes the position (indicated by the dotted lines),

it suddenly tilts the gutter F over, so that the new liquid to be measured is obliged to fall into the other tank, when the same operation as already described is repeated. It will thus be seen that both tanks are filled automatically with fresh liquid, while the measured liquid runs away into a reservoir or other receptacle as required. Meters of this description have been made to weigh one ton of cane juice per minute.

While, however, it is felt that automatic measurement of juice is a great desideratum, considerable hesitation is shown in adopting automatic measurements, and it is generally felt that the simple system of tank measurement is the most reliable in practice. To facilitate also the calculation of the weight of the juice from the specific gravity, it is advisable that the hydrometers used should show the specific gravity at the temperature of observation, water at 62° Fahr. being taken as unity; the observed specific gravity will then give, as an easy calculation, the true weight of juice; thus, a gallon of juice of which the specific gravity is 1·070 will weigh 10·70 lbs. to the gallon.

For the credit side of the boiling-house balance-sheet, as with that of the factory as a whole, the sucrose in the sugar and refuse molasses forms the asset. In this case the sources of loss are—the filter-cake, inversion, and entrainment, together with the necessary washings of the juice, syrup, molasses tanks, etc. The loss from the first two of these causes is ascertainable, the analysis and weight of the filter-cake, and the relation of the crystallisable to the uncrystallisable sugar in the juice and syrup affording the necessary data. The remainder are included under the heading of Unknown Losses.

Proceeding in this way, information is obtained which enables balance-sheets on the following basis to be drawn up:—

I.—GENERAL BALANCE SHEET

Dr.	Cr.
Sucrose entering factory as cane	Sucrose recovered as 1st sugar .. .. ..
	Sucrose recovered as 2nd sugar .. .. ..
	Sucrose recovered as 3rd sugar .. .. ..
	Sucrose in megass .. ..
	,, in molasses .. ..
	,, in filter cake ..
	,, lost by inversion ..
	,, lost by entrainment, etc. ..

II.—MILL HOUSE BALANCE SHEET

Dr.	Cr.
Sucrose entering mill house as cane	Sucrose in juice expressed
	Sucrose lost in megass ..

III.—BOILING HOUSE BALANCE SHEET

Dr.	Cr.
Sucrose in juice expressed	Sucrose recovered in 1st sugar .. .. ..
	Sucrose recovered in 2nd sugar .. .. ..
	Sucrose recovered in 3rd sugar .. .. ..
	Sucrose in molasses .. ..
	,, in filter cake ..
	,, lost by inversion ..
	,, lost by entrainment, etc. ..

I. and III., to be quite accurate, have to be made out for the whole grinding period, on account of actual figures for second products not being available until the end of any particular campaign. Approximate results can, however, be given for each week, if desired, by careful stock-taking and estimation of the sugar returns of the produce on hand at the beginning and end of the week.

Another useful way of stating the results of factory working is the following:—

Sucrose in canes	100	—
,, megass	—	—
,, juice	—	100
,, 1st sugar	—	—
,, 2nd sugar	—	—
,, 3rd sugar	—	—
,, molasses	—	—
,, filter cake	—	—
Lost by inversion	—	—
,, entrainment, etc. ..	—	—

The above constitutes the essential part of chemical control in connection with the actual manufacture of sugar. In addition, records are kept of the composition of the megass, the several mill juices, syrup massecuites, and molasses, so that the figures may be properly considered. Thus, if the sucrose expressed from the cane is not what may be looked upon as showing reasonably good work, reference is made to the composition of the canes as regards fibre and the description of canes ground, and allowance made accordingly. In a similar manner, the composition of the juice—the proportion of impurity in relation to the cane sugar and glucose—or the relation of the two latter to one another, gives important information in drawing conclusions from the balance-sheet. In association with

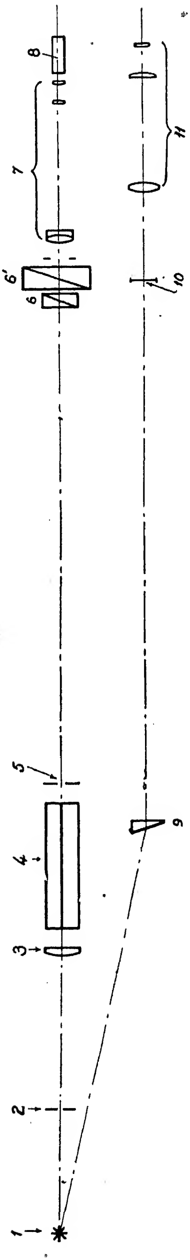

FIG. 204A.—Diagram showing construction of saccharimeter.

the engineer, the chemist has duties in connection with the boiler plant; but these, as well as the question of the scientific control of the distillery, will be dealt with when those important adjuncts to a sugar factory are considered.

The most important of the apparatus used in the scientific control of a sugar factory is the polariscope or saccharimeter. The instrument has now been brought to a very high degree of efficiency after about forty years' constant improvement, and if reasonable care is exercised, sugar contents of solutions can be determined accurately to within 0·05 per cent. The use of the saccharimeter depends on the fact that sugar is an optically active substance. That is, it possesses the property of rotating the plane of polarisation of a beam of plane polarised light through an angle, the magnitude of which is directly proportional to the concentration and to the length of column of liquid employed. The actual angular rotation produced by the solution is in practice not measured, but is compensated for by introducing a known thickness of crystalline quartz which is also optically active. Some crystals of quartz rotate the plane of polarisation to the right and others to the left,

and a suitable combination of the two will give all the compensation which is required in a saccharimeter.

The diagrammatic construction of a modern instrument is shown in Fig. 204A, the actual in Fig. 204B.

The light source is situated at (1) and enters the instrument through a small aperture (2), and is converted into a parallel beam by the glass condenser lens (3). The double prism (4) is so constructed from Iceland spar that the

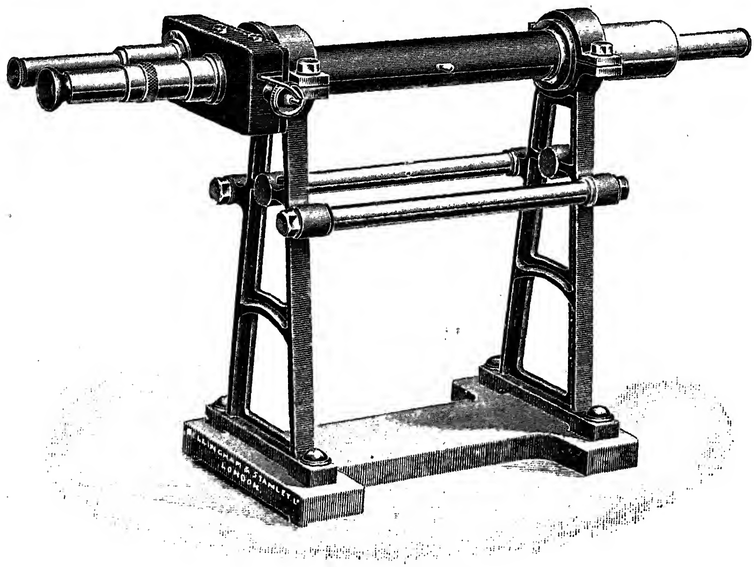

FIG. 204B.—Saccharimeter.

light after passage through is composed of two parallel beams whose planes of polarisation are inclined to each other by an angle of about 7°. A diaphragm is placed at (5) to present a circular field when viewed by the low power telescope (7). The analysing prism is situated at (8) and the compensation double wedges at (6) and (6′). The larger of these moves in a slide across the axis of the instrument. This large double wedge is constructed from two halves, one half being a wedge of right rotation quartz while the

other half is of left rotation quartz. Therefore as this is moved more or less rotation is produced either to the right or to the left to compensate that of the solution. The slide carrying the wedges is also provided with a scale on glass situated at (10) and is read by transmitted light by means of a low power telescope (11). This telescope carries a vernier so that the scale may be read directly to $\frac{1}{10}$ division—*i.e.*, 0·1 International Sugar Scale or by estimation to 0·05. The tube containing the sugar solution is inserted in the trough of the instrument between the diaphragm (5) and wedge mounting.

The most convenient light source to employ is the half-watt electric lamp. If this is not available, incandescent gas or oil can be employed, but whatever source is used care must be taken to insert an efficient diffusing screen between the light source and the instrument. If electric light is used a separate lamp should be mounted entirely apart from the instrument, as electric lamps mounted in the instrument, as is sometimes the case, are not satisfactory and replacements are often difficult to obtain.

In practical use, owing to the fact that the rotatory dispersive power of sugar and quartz are not identical, the quartz wedge system does not return exactly the plane of polarisation for all colours to the original position after rotation by the solution tested, and this results in the two halves of the field not matching exactly in tint, and different observers will obtain variation in measurement. To compensate for this the field may be made uniform in tint by introducing a colour filter, and a cell containing potassium bichromate is used or its equivalent in coloured gelatine. If the bichromate solution is employed the standard thickness is 15 mm. with a 6 per cent. solution.

Quite recently variations were found in the scale length of saccharimeters, especially those of Continental make, differences of no less than 0·3 of a degree having been found between the 100° points of saccharimeters recently coming from that source. This variation is a most serious fault and may lead to considerable loss. In the instrument described, which is of British design, this fault has been entirely overcome, as, owing to the compensation wedge being comparatively small and circular, it can be rotated in its own plane after the instrument is finally assembled and a position found where the scale is correct. This adjustment is now carried out at the National Physical Laboratory at Teddington with the greatest of care, and a certificate is supplied with each instrument.

This adjustment is embodied on the wedge mounting, and allows of the instrument being modified at a later date to suit any modification which may be made in the value of the normal weight in future.

Another important instrument in connection with modern sugar factory control is the refractometer, Fig. 204c, which affords a means of estimating the solids in a solution. This instrument differs fundamentally from the polariscope in that its readings are virtually measurements of the velocity of light in the substance under test, as distinct from the measurement of the angular rotation of the plane of polarisation, which is the basis of all polariscope readings. Another difference between the two instruments is that while the polariscope reading is the algebraic sum of left- and right-handed sugars, which may be present in the solution under test, the refractometer reading is a measure of the total solids present.

Essentially the refractometer consists of two similar prisms of suitable glass placed very nearly in contact and held in position by hollow brass castings through

which water can be circulated in order to control the temperature of observation. The brass castings forming the prism box are hinged together, and when opened a few drops of the liquid to be tested are placed upon the surface of the lower prism. The act of closing the box squeezes the liquid into a thin parallel film, which fills

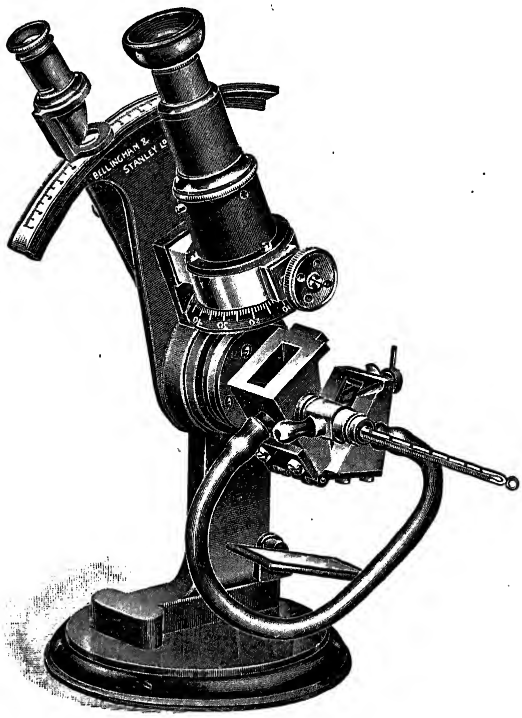

FIG. 204C.—Refractometer.

the small space between the prisms. The mirror below the prism box is then inclined in such a way that light is reflected through the prism box.

On looking through the observation telescope, while the prism box is gently rocked to and fro about its axis, a position will be found at which the field of view is divided

into a light and a dark part, separated by a band of colour. Just above the prism box, at the right-hand side of the instrument, is a milled ring which actuates the compensator whose function is to eliminate the coloured band and to divide the field of view sharply into light and dark halves. The line dividing the light and dark halves can be thus adjusted so definitely that its coincidence with the intersection of the cross-wires seen in the telescope can be determined with accuracy and certainty.

The amount by which the prism box is inclined with respect to the axis of the telescope is a measure of the optical density of the material under test, which can be read directly upon the divided arc of the instrument. In the case of sugar solution, it is generally convenient to have an additional scale engraved upon the arc to read directly the percentage of water present.

For forty years prior to 1914 no attempt had been made to improve the refractometer, the optical design of which was in some respects defective. One of the most serious defects was that which limited the use of the instrument to liquids having a refractive index below 1·52, despite the fact that the arc was divided to 1·70. This was clearly due to an oversight in optical design, the lower (or illuminating) prism being made of glass having a refractive index of about 1·52, and with such a prism in contact with a liquid having a greater refractive index the light from the mirror is simply reflected—in accordance with a well-known law of optics—from the liquid-glass interface.

This fundamental error of construction has now been overcome by the use of a suitable glass for the lower prism.

CHAPTER XI

STEAM GENERATION

A SIMPLE description has now been given of the manufacture of sugar from the sugar-cane. This account, from the planting of the gigantic grass, the *fons et origo* of this interesting industry, to the deposition of the manufactured and marketable sugar crystal in the sugar store, has been carried through without a break, and without reference to side issues which are calculated to tend to withdraw attention from the main subject. At the same time it will have been apparent to every reader that a powerful motive agent has been ever present throughout the entire process, by the utilisation of which the above transformation, from plant to crystal, has been effected. On most pages the presence of " steam " has been indicated in some direct or indirect form, and its application to the engines and general machinery, as well as to the cane juice itself, has been very frequently noted. It is now necessary to explain whence this important agent has been obtained, and to describe the means whereby it has been generated.

A complete sugar factory may be said to be compounded of three separate and distinct sections, viz. the mill-house, the sugar-house, and the boiler-house. To these may be added a fourth department, in connection with which the manufacture of rum and other by-products may be conducted. It is to the boiler-house and its operations that attention will now be directed, and, in passing, it may be observed that it is conducive to smooth

work and the diminution of noise, dirt, and confusion, when these respective departments are self-contained and as much shut off from each other as possible. A trifling increase in the difficulty of ready supervision may thus be incurred, but, if possible, this slight inconvenience should be boldly met and overcome in a more thorough way than by permanently saddling those sections of the factory which require seclusion and cleanliness with the drawback of constant association with the noisier and dustier sections.

The transport of the sugar-canes to the mill-house, and their treatment in the cane-mills, have been fully described, the action of the latter culminating in the separation of the woody matter or megass of the cane from its contained juice. The progress of this juice through the sugar-house, and its ultimate conversion into sugar crystals, have already been followed, and the next step is to accompany the megass to the boiler-house and witness the means by which it is utilised in the furnaces for the generation of steam.

Before entering upon any detailed description of a modern sugar factory's boiler-house, reference should first be made to the more primitive arrangements which obtained in earlier times, and are in many instances still employed, with regard to the use of megass as a fuel. In connection with the working of common-process and other factories in which the copper wall is the chief evaporator and concentrator, comparatively trifling quantities of megass are burnt directly beneath any form of steam-boiler. Instead of passing it direct from the mills to the boiler-house, the more general custom is to convey the megass from the elevators to "logies," or megass storage-sheds, where it is left to dry before being used as fuel. Sometimes this slower process is hastened by spreading the megass in the sun, at the cost of the expenditure of a considerable amount

of labour, the use of logies being, however, thus more or less avoided. Secheries, a somewhat elaborate mechanical and structural arrangement for more rapidly drying the megass by the application of the waste heat from the boilers on its way to the chimney, have also been largely employed on many sugar estates, but their services are gradually and rapidly being dispensed with, and it is now generally recognised that a well-designed and efficient type of megass furnace is the best form of megass drier that can be conveniently used. Logies and secheries are an abomination and nuisance in more senses than one, and their continued employment should be systematically discouraged.

Ultimately, when ready for use, this valuable refuse is taken to the copper-wall furnaces, and burnt therein, to boil the juice which is being concentrated in the tayches, the residue or waste gases being ultimately passed through the tubes of a multitubular boiler. This apparatus has been shown in two of the earlier illustrations, Figs. 111 and 112. In the case of common-process estates, the whole of the steam required for the factory is frequently obtained in this way; while in some instances an additional and independent steam-boiler is held in reserve for the purpose of using up any surplus store of megass and extraneous supplies of cane-trash and wood fuel, and thus meeting any passing demand for an increase of the steam supply. In the case of factories in which the copper wall is used in conjunction with the vacuum pan similar working arrangements are in vogue, and considerable quantities of imported coal, occasionally supplemented by trash and wood, are consumed to supplement the megass, and thus cope with the extra demands of the extended and more perfect process. When multiple-effect evaporators supplanted the old-time copper wall, it became necessary to burn the whole of the megass in the steam-boiler furnaces. This raised the question of the best

method of realising the full heat-value of the megass, such effort being more especially stimulated by the fact that the employment of fuel-saving multiple-effect evaporators brought within view the possibility of abolishing the necessity of any coal or wood consumption whatever, and the avoidance of burning cane-trash which ought properly to remain in the cane-fields. The attainment of this end is a goal well worth reaching by every legitimate effort which can possibly be made; and, as labour-saving considerations likewise assume considerable importance, a double effort has generally been instituted both for making the most of the megass, burning it direct from the cane-mills, and for abolishing logies and secheries and their disagreeable and expensive labour accompaniments.

A visitor to a modern sugar factory's boiler-house, witnesses, therefore, in the first instance, the arrival of the moist megass direct from the cane-mills, from which it has been brought by suitably designed conveyers, which distribute it amongst the various furnace feed-hoppers as required. It contains more or less moisture, is more or less finely divided, and is hotter or colder according to the varying nature of the treatment it has received in the mills.

Fig. 205 gives a good general idea of the manner in which a megass-boiler furnace is supplied with its special class of fuel, and in many respects it may be taken as a typical instance of one convenient method of conducting such supply. It also serves to explain approximately the characteristic class of external furnace, built in brickwork, which it is necessary to employ for the purpose of the efficient consumption of this description of moist fuel. The "green megass," B, first falls from the conveyer on to the firing platform, P, and forms the heap of megass, A, which will serve as a useful and convenient fuel reserve, should a short stoppage of the cane-mills take place at ar

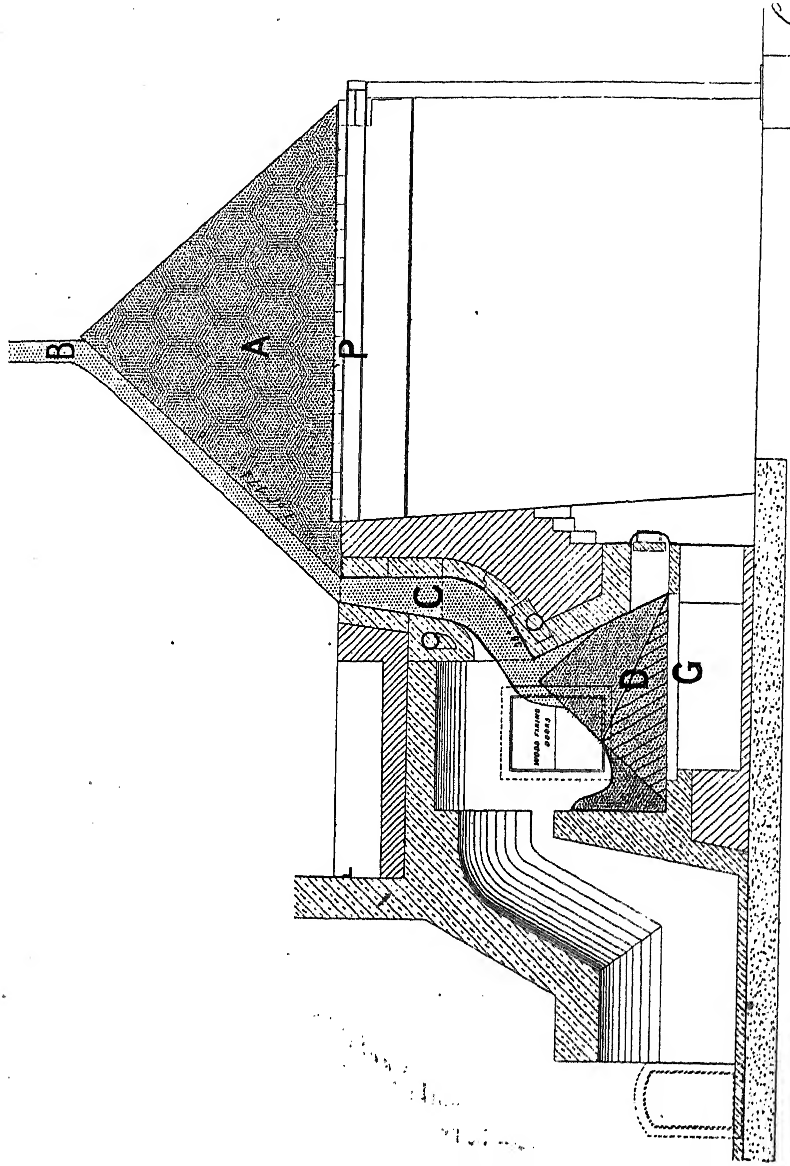

FIG. 205.—Longitudinal section of a steam-boiler furnace used for burning moist megass fuel.

When this heap has attained a sufficient size, it acts as a slide, or shoot, down which the green megass can reach the furnace hopper C, passing through which it accumulates on the fire-grate G in the form of the heap D. When the apex of the latter has been raised to the point shown in the illustration, it acts as a " stop," and the green megass then accumulates in the hopper C; and, were no fire lighted, it would remain stationary, as shown. When, however, the furnace is at work, the consumption of the heap of megass D causes the apex to settle downwards, and such subsidence removes an obstacle to the incoming megass, which is awaiting this opportunity of entering the furnace. In actual practice this action virtually culminates in a continuous feed of the fuel to the fire-grate, and all that has to be done is to keep the hopper sufficiently supplied with megass, one fireman attending to several furnaces. Fig. 206 shows the application of such a furnace to a well-known type of water-tube boiler, and more generally elucidates various points which have to be observed when using green megass fuel.

Whatever class of boiler happens to be fired with megass, it is essential that an external furnace, or brick oven, should be used in conjunction with it. Green megass cannot be dealt with in the same manner as coal, and any attempt to burn it on an ordinary coal-grate, and in close proximity to the water-cooled heating surfaces of the boiler, is certain to end in failure. It is essential that complete combustion of the fuel in the furnace should be effected before the products reach the boiler, the highly heated gases and flames subsequently passing through suitably arranged flues to the latter, and opportunity is sought for making sure of this indispensable condition. Moreover, in the case of green megass furnaces, a double duty is thrown upon them; for they have in the first place

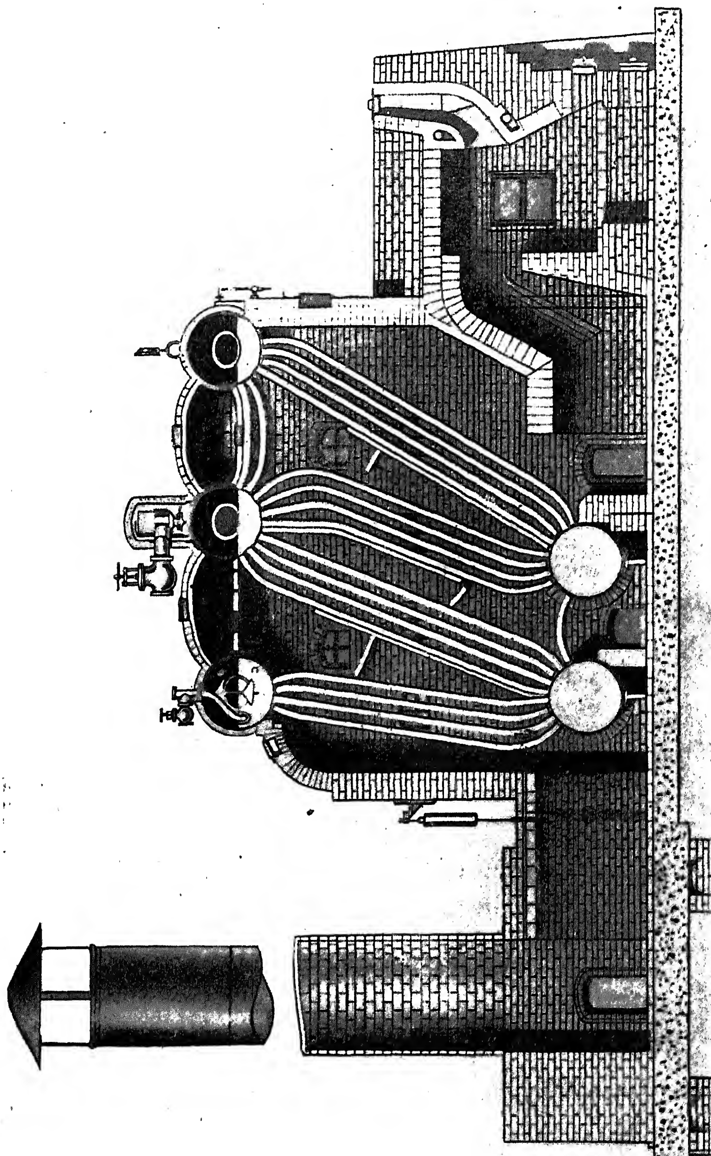

FIG. 206.—Longitudinal section of a water-tube boiler with megass furnace.

to dry the fuel, and subsequently to consume it to the best possible advantage. To this end it is imperative that each furnace should be constructed of refractory materials, such as brickwork, which will absorb and store up heat to an intense degree, so as literally to roast the fresh and moist fuel the moment it enters the furnace. The considerable amount of fuel which has to be kept constantly burning, coupled with the large quantities of vapour and gases thus generated, and the volume of air required for proper combustion, together with the desirability of an intimate

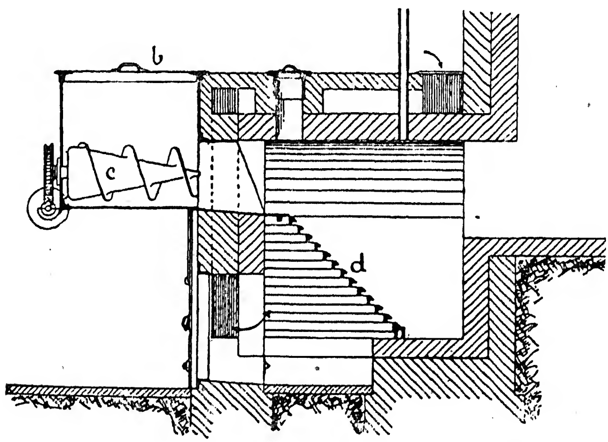

FIG. 207.—Longitudinal section of a mechanically fed megass furnace.

mixture of the consequent products, call for suitable accommodation in a sufficiently roomy furnace chamber. Hence the large cubic capacity characteristic of these structures, the precise proportions and shapes of which necessitate very careful consideration. The very finely divided condition of the fuel, of which considerable percentages appear in the form of sawdust or "cush-cush," is a point which must not be lost sight of. The megass should therefore, as far as possible, be lightly compressed and quietly deposited upon the heap of burning fuel, otherwise it is in

danger of being swept forward by the draught in an unconsumed condition and wasted up the chimney. This can be avoided by proper furnace-feeding arrangements.

One of the oldest and most efficient of these Dutch-oven furnaces is shown in Fig. 207. In this case the megass is introduced into the feeder at *b*, and is slowly forced forward into the furnace by the revolving screw *c*. The grate *d* is arranged as a tier of specially formed fire-bars which avoid waste of fuel, and permit of the provision of very large air

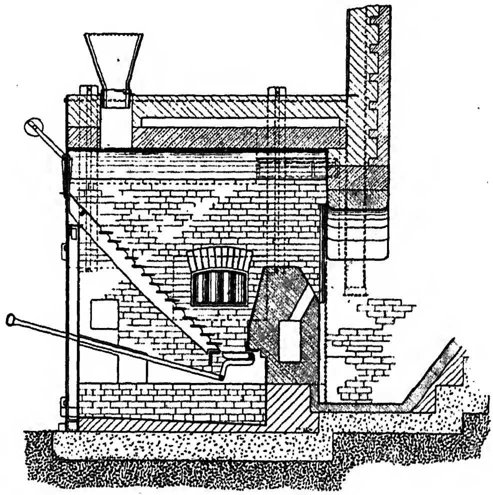

FIG. 208.—Longitudinal section of a ladder-grate megass furnace.

spaces between the bars. This tier of bars usually assumes the form of a truncated semi-cone, down the surface of which the megass slowly creeps as it is being consumed. In this oven are to be found the elements of a well-fed furnace, which, coupled with a careful regulation of the speed of the feeding-screw, will give excellent results, and minimise the waste of the sawdust present in the megass.

Another form of these furnaces, which in certain localities is probably in more general use than any other, is seen in

Fig. 208. One of the chief characteristics of this oven is that it is furnished with a ladder-grate, which provides large air

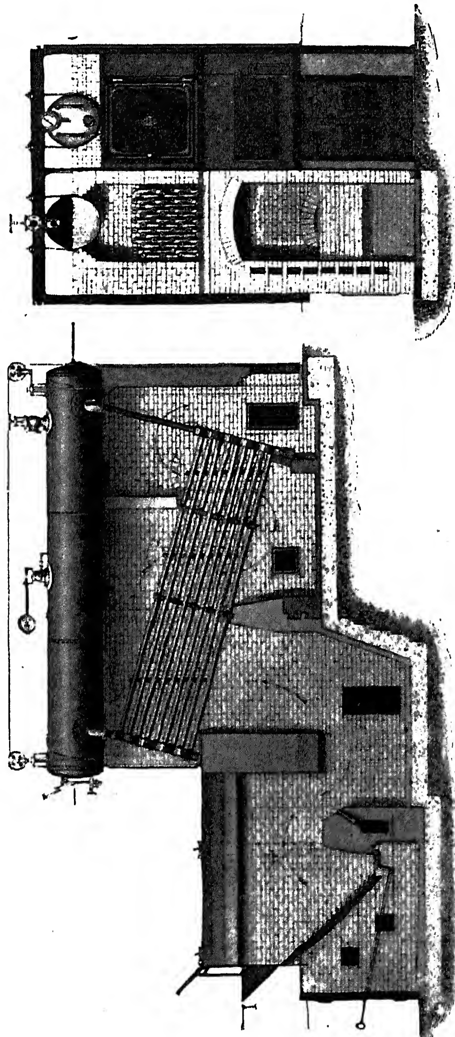

FIG. 209.—Longitudinal and cross sections of water-tube boilers worked in conjunction with ladder-grate furnaces, with hot-air passages in furnace side walls.

spaces between adjacent bars without waste of fuel. At the foot of this is fixed a horizontal tilting-grate, which greatly facilitates the periodical cleaning of the furnace, a

fairly frequent need which should never be overlooked in the design of these structures. In this case the fuel enters through the overhead trap-door and hopper, falling thence on to the large heap of roasting and burning fuel which, as already observed, is usually found to be present in this class of oven. Fig. 209 shows such a furnace applied to a straight-tubed water-tube boiler.

A further development of these ovens is shown in Fig. 210. This furnace is formed in the shape of a

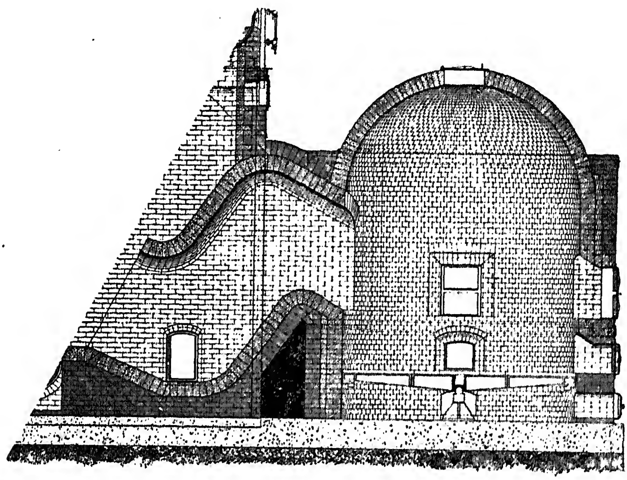

FIG. 210.—Section of circular megass furnace fitted with a circular revolving grate.

capacious domed cylinder, fitted with a circular and horizontal revolving grate, the latter convenience promoting increased facilities for cleaning the furnace of clinker. This class of furnace is peculiarly applicable when several boilers are fired from one and the same oven, and its efficiency has been most marked. In several of the above structures large wood-firing doors are in evidence, and these are of considerable dimensions and placed a good height above the fire-grate, so as to enable a full charge of wood, when used,

to be rapidly thrown on the grate. It is the absence of suitable provisions of this nature which so frequently prejudices the results obtained from the use of this somewhat cumbersome and unmanageable form of fuel, which demands special facilities if its occasional services are to prove acceptable.

Some thirty years ago two French engineers noticed that they obtained about 7 per cent. greater efficiency in summer than in winter from the same boilers under the same conditions, and ultimately, surmising that the gain might be due to the greater temperature of the air in summer, they made comparative trials which finally confirmed their suppositions, and led them to believe that the gain in efficiency was chiefly due to the better combustion of the gases with heated air. It was also observed that with heated air the flames were much shorter and more white, and that there was notably less smoke from the chimney. In connection with the consumption of moist megass, a recognition of this principle has promoted increased efficiency, and it is a frequent practice in the construction of megass boiler and furnace settings to arrange for its adoption. To this end the boiler setting itself may be surrounded with suitably-arranged air-admission channels which lead into similar channels and chambers surrounding the furnace, ultimately passing through the furnace check-wall, as seen in Fig. 209. By this means loss of heat, due to radiation from the boiler settings and furnaces, is minimised. The air ultimately used beneath the furnace grate is gradually heated to considerable temperatures, and as it absorbs more moisture than cold air a smaller proportion of the calorific value of the megass itself is required for evaporating the moisture in the fuel. Experience has shown that it is an advantage to use megass fuel as promptly and as hot as possible, and at the same time to obtain a heated air supply for use in the

furnace. As this fuel is always more or less heated by the treatment it has received in the mills, it is important not to lose sight of the advantage which may be gained by not allowing it to cool before being used; for any contribution of this description, however small, which tends to maintain the highest possible temperatures in the furnace, is an aid to the attainment of the best results.

An artificial as well as heated draught is frequently used beneath the grates of these furnaces. Its application, however, requires the most careful consideration of the conditions involved, owing to the comparatively low specific gravity of dry megass, coupled with its finely divided condition.

In colonies where earthquakes and hurricanes have to be reckoned with, and where factory chimneys must therefore be kept as squat as possible, a system of induced draught may be advantageously employed, and with certain classes of furnaces its use may be said to be safer and less liable to lead to any waste of the finer portions of the fuel than would be the case with direct forced draught acting immediately beneath the furnace grate. From information obtained from numerous boiler tests, it would appear that in the case of a natural draught the best results are obtainable with a damper-controlled chimney draught of fully seven-tenths of an inch of water in the main chimney flue, and this figure may be accepted as a fairly safe guide when arranging for the installation of artificial draught in connection with the consumption of megass fuel. Fig. 211 explains the application of an induced draught to a straight-tubed water-tube boiler, whilst Fig. 212 gives a front view of direct hot-blast furnaces at work in connection with four similar boilers. An idea is also obtained of the manner in which the megass is conveyed from the mill-house to the furnaces and subsequently distributed to

the latter. In this case there is an extended use of mechanical appliances for the actual feeding of the fuel into

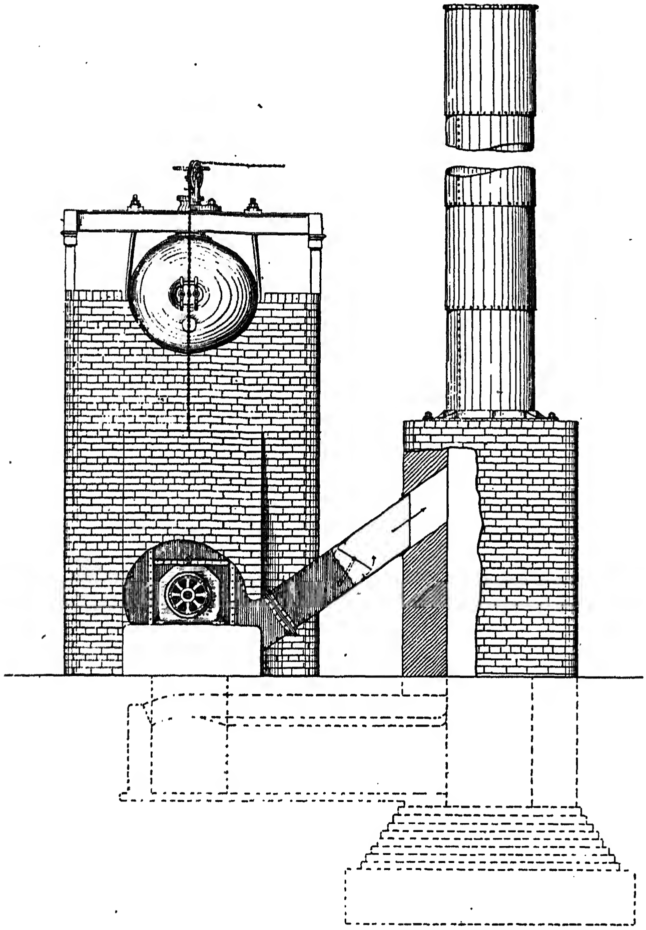

FIG. 211.—Water-tube boiler worked in conjunction with an induced draught.

the furnaces, which may be usefully compared with the less elaborate method shown in Fig. 205.

Enough has now been said for the purpose of explaining the general conditions under which green megass has to be

utilised for raising the major percentage if not the whole of the steam used up in a sugar factory. As in the case of almost every other of the appliances employed in the manufacture of sugar, so also in that of these special furnaces it may be said that they are to be found at work in a great variety of forms. Most manufacturers and engineers have their own special views regarding the best style of furnace to meet specific conditions, which show themselves in

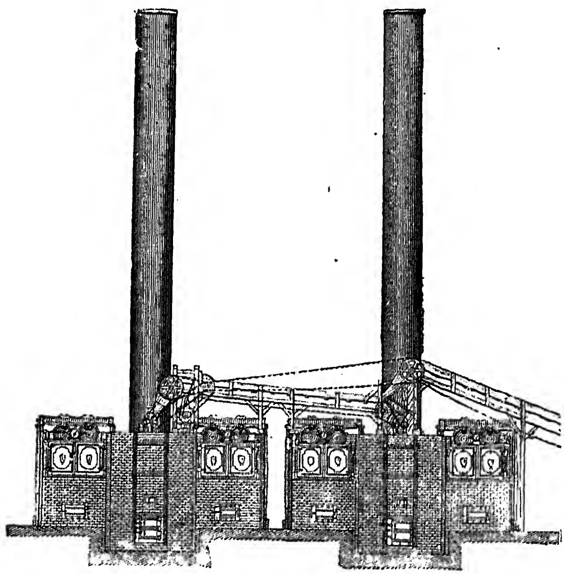

FIG. 212.—Water-tube boilers worked in conjunction with direct forced hot-blast draught.

almost every conceivable design employable, and in divers countries a great difference of opinion prevails as to the best proportions of grate area and furnace draught that ought to be applied. Local conditions must receive very careful consideration, and a taller chimney may be associated with a smaller grate area, while the megass from very sweet and woody canes will not present the same difficulties of consumption which are experienced and have

to be overcome when comparatively rank and immature canes have been ground in the mills.

With reference to the undoubted success that has more recently attended persistent efforts to improve the efficiency of megass furnaces, it is perhaps desirable to state here that, in numerous instances, such efforts did not meet with full success until after the introduction and use of a mechanically produced draught. The employment of a fan to supplement the pull of a chimney of moderate dimensions ensures a more uniform and certain control over the air-supply to the furnaces, which are thus practically rendered more independent of atmospheric conditions, and are also less liable to be adversely affected by the ever-changing qualities of the megass fuel supply, or by certain drawbacks that would be otherwise experienced through the employment of economisers. By means of a mechanically produced draught a sound basis is established upon which well-regulated experiments in connection with furnace improvements can be satisfactorily and profitably prosecuted. There are two systems—forced or induced—under which such draught can be utilised, and it is even an advantage to use simultaneously both a forced draught fan for the precise regulation and supply of air to the furnaces as well as an induced draught fan to control the removal of the waste gases from the boiler flues and forward them in a carefully regulated current to the chimney, and thus ensure a "plenum" in the flues of the boiler settings, with the consequent avoidance of an excessive cold-air leakage through the joints of the brickwork. The latter should at all times be maintained in scrupulously good order, and should periodically be externally painted with suitable applications, such as an asphaltum varnish, which should preferably be applied when the boilers are at work, so that any serious air leakages may be the more readily detected and stopped.

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Now that the employment of economisers is becoming more prevalent on sugar estates, some form or other of mechanical draught becomes all the more essential; and, indeed, if the fullest possible benefits are to be derived from the installation and use of an economiser, a mechanical draught may be said to be practically indispensable. A chimney draught, by itself, may be regarded as insufficient for the attainment of the best possible results, as it is entirely dependent on a high temperature in the waste gases. When this otherwise lost heat is utilised in an economiser for the heating of the boiler feed water, some other and less wasteful means of draught production must be substituted, and the installation of a mechanically produced draught solves the problem—and the steam-consumption of a properly arranged installation of this description will not exceed $1\frac{1}{2}$ per cent. to 2 per cent. of the total steam generated.

In order to obtain the best possible results, the use of an economiser or feed water heater is essential. By such means a large amount of the available and otherwise waste heat in the flue gases is utilised. In the absence of some system of mechanical draught the necessary average gas-temperature at the base of the chimney may be taken as from 550° Fahr. to 600° Fahr. With a well-arranged installation of economisers and fans this temperature may be reduced to 300° Fahr. without prejudicing the work of the furnaces, the difference in temperatures representing an enormous increase in efficiency and working economy.

Turning attention more particularly to the various types of boilers which have been used on sugar estates, and to those forms which are coming more and more prominently to the front at the present day, it may be observed in the first place that such generators as are generally used

on sugar estates may be roughly divided into three classes:—

(1) Tank, or shell boilers.
(2) Fire-tube boilers.
(3) Water-tube boilers.

Class 1 comprises the many varieties of cylindrical boilers, of a more or less comparatively simple type, which are generally used in connection with coal fuel. Their external form in most cases virtually assumes that of a plain cylinder with flat ends. Internally they may be constructed with a great variety of modifications, which have for their object the efficient transmission of heat to the contained water, the latter being present in considerable bulk; and the various further ends they are designed to meet are as to strength, durability, size and weight, saving of labour and material, and improvement of water circulation, coupled with facilities for examination, cleaning, and repairs. When coal has to be used in a sugar factory, various forms of these steam generators are usually employed in connection with its consumption, although, even for this description of fuel, water-tube boilers have already been occasionally adopted. In one sense, tank boilers are also fire-tube boilers, inasmuch as they contain one or more large-sized horizontal firing flues which are of considerable diameter. Within these flues and within the boundaries of the main shell the coal fire-grates are located, the balance of such flues serving as conduits for the products of combustion as they pass through the boiler.

Class 2 (fire-tube boilers) comprises shell boilers of a comparatively limited number of types. In fact, so far as sugar estates are concerned, it may be said to have reference to one particular form of multitubular boiler. In such a steam generator the coal or megass furnace is located wholly outside the boiler shell, and the one or two fire-tubes

of large diameter and comparatively thick plates, which are special characteristics of the tank boilers, are now supplanted by numerous horizontal fire-tubes of very small diameter, made of thin plates. The latter are introduced for the purpose of gaining more heating surface of increased efficiency within any given space. The water contents of the boiler shell are likewise broken up and divided by these tubes into rather shallow films, or connected water sections, and the mass of water, as a whole, is thus permeated by the largest useful number of heat-distributing channels. The crowding of these fire-tubes in a multitubular boiler is often carried to an extreme. Heating surface in the abstract is one thing; its efficiency is another. It should be borne in mind that the lower circumferential sections of the tubes are of somewhat diminished value for the purposes of steam generation. Not only has the generated steam comparative difficulty in escaping from the outer and under sides of the tubes, but such generation is still further hampered by the deposit of soot and ashes which occurs on the inner side of the same sections of the horizontal tube surfaces, a specially brisk chimney draught being desirable in connection with the use of boilers of this class, in order to minimise this last contingency.

Class 3 (water-tube boilers) comprises boilers which possess characteristics totally different from those distinguishing either of the two foregoing types. In the case of Class 2, the hot gases, as just explained, pass through the numerous tubes which are surrounded by water. In the case of Class 3 this arrangement, or system, is reversed, and the tubes are surrounded by the flames and gases, while the water is contained within the tubes themselves. The water-tube boiler, as considered under this classification, is in no sense a shell boiler. Broadly speaking, it is an extensive collection of water-tubes of small diameter which

form the bulk of the heating surface, attached to suitable "headers," and massed together within a refractory setting or chamber. When employed in connection with the consumption of coal fuel, the furnaces are almost invariably contained within the boundaries of such setting. But if megass is the source of applied heat, the furnace forms an external addition to the normal installation. This description of steam generator appears in some sixty varying forms, of which some six or seven examples may be said to be more especially applicable to use on a sugar estate, more precise details being given below.

The fire-tube multitubular boiler (Class 2) has been more largely used in sugar factories than any other steam raiser ever made. From the earliest days of the application of steam power to the tropical sugar industry, to the present time, it has nearly always been in evidence, and it is to a greater or less extent in use upon almost every estate. Fig. 213 explains the type of boiler referred to, and an earlier illustration, Fig. 112, has portrayed its earliest application to work on a sugar estate, whilst Fig. 214 gives a full idea of one of the best ways of independently setting such a boiler in conjunction with any type of megass furnace which may be preferred. From this plan it will be seen that the products of combustion from the furnace first pass underneath the boiler. Then, turning upward, their direction is reversed, and they pass along both sides of the shell, reuniting in the front combustion chamber, whence they enter the tubes on their way to the smoke-box and the chimney flue. In this way extensive combustion chambers are provided, which afford the fullest opportunity for complete combustion and efficient consumption of the constituents of the megass before the products enter the confined areas and spaces of the tubes, and excellent results are obtained. When the employment of the copper wall is

minimised, owing to the introduction of the vacuum pan, or abandoned, owing to the ushering in of the multiple-effect evaporator, these fire-tube boilers are usually installed somewhat as above, with variations of the furnace and setting, according to local preferences. At the present day modern sugar factories of the highest standing are supplied with steam raised in boilers of this description alone.

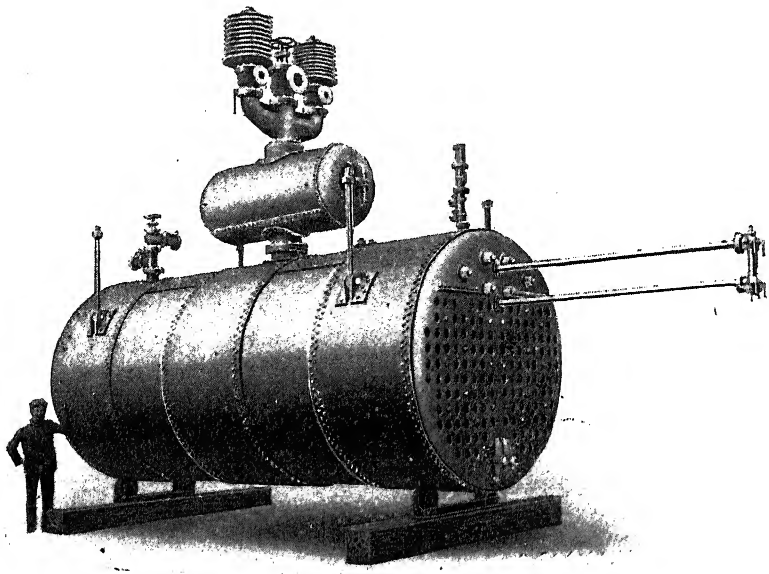


FIG. 213.—General view of a multitubular boiler.

During the period of complete transition from the older to the newer processes a practice was temporarily in vogue of employing a considerable variety of steam generators, and in those days the boiler-house of a sugar factory frequently contained a curious and interesting conglomeration of types awaiting the survival of the fittest. Compound Lancashire and multitubular, compound Cornish and multitubular, and compound Galloway boilers were all tried, to say nothing of the simpler forms of tank boilers

—Cornish, Lancashire, and Galloway—and Dry-back generators. In the midst of these one generator more especially proved itself to be a great convenience, as well as an efficient steam raiser in connection with the use of megass fuel. It is shown in Fig. 215. In this connection it may be observed that whilst the specific gravity of coal ash may be taken approximately as standing at about 1·73 and over, similar figures for megass ashes stand at about 1·05 and under, a circumstance and difference which accounts for the very considerable distances to which the latter are swept away by the chimney draught. In the case of multitubular or fire-tube boilers, as already observed, they frequently lodge within and choke the comparatively long and narrow tubes, thus necessitating the duty and the labour of regularly sponging the latter at stated intervals of about twelve hours, a task which entails considerable time, effort, and very careful supervision, more especially if these boilers are to be maintained at their maximum efficiency. In the case of the wood-burning Galloway boilers (Fig. 215), owing to the spacious flue-passages winding among the short-coned and vertical water-tubes, and the characteristic contour of the latter, the light ash is so effectually swept away throughout the boiler and its adjacent flues that a generator of this type can be used without intermission throughout an entire crop, and maintain a fairly uniform efficiency from the beginning to end of the campaign without cleaning. In using these boilers in conjunction with megass fuel, the products of combustion may either pass first along the bottom of the shell and then through the tube chamber; or they may first enter the tube chamber, proceeding thence along the sides of the generator and under the bottom to the chimney flue.

It will not, in this work, be necessary in dealing with the subject of water-tube boilers to do more than call the

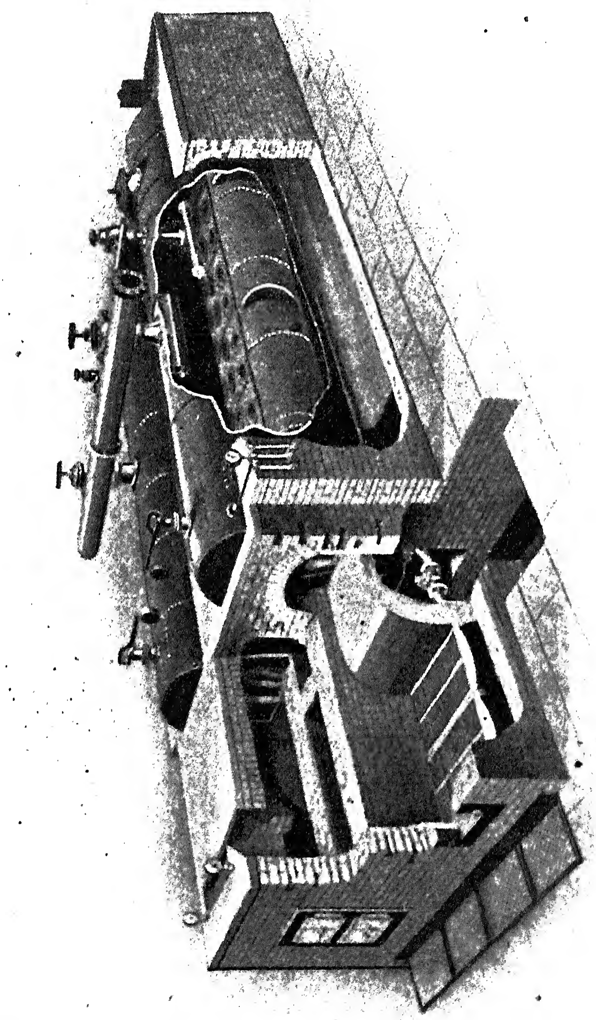


FIG. 215.—Sectional view of wood-burning Galloway boiler, showing the internal chamber full of vertical water-circulating tubes, which extend throughout the entire length of the boiler.

attention of the reader to the leading types of these generators which have either come into pretty general use or may commend themselves to the careful consideration of colonial

steam users. Suffice it in passing to say that to impart the heat from the furnace gases to the boiler heating surfaces a brisk gas circulation is very necessary, while a correspondingly brisk water circulation is equally essential to transfer the heat from the plates to the water. In all types of boiler every care is supposed to be taken to ensure the best water circulation obtainable, and so well is the importance of this point realised that in many cases artificial means of circulation have been tried. Certain types of water-tube boilers appear intrinsically to offer decided advantages for satisfying the above-mentioned requirements, and the bulk of the heating surface is formed of very thin plates, coupled with a considerable subdivision of the water contents of the generator. They are, therefore, very rapid steam raisers, and have likewise shown themselves to be very economical of fuel. In those sugar factories which are shut down for some nine hours every night of the campaign, the rapidity with which steam may be raised in a morning, through the use of these generators, is a factor of the greatest importance. Furthermore, the manner in which water-tube boilers are constructed, and the characteristic form of the majority of the "settings" within which they are installed, offer additional advantages which promote the prompt resumption of the work of the factory each morning. Such installations, as described above, may be regarded as a collection of numerous water-tubes of small diameter and of correspondingly thin metal plates, enclosed in a capacious refractory chamber with walls of considerable thickness, which themselves form effective storage reservoirs of heat accumulating during the day's work. No thick shell plates intervene between this setting and the tubes, and throughout the night the regenerative action of the hot brickwork upon the tubes and their contained water usually guarantees the maintenance of considerable steam

pressures in the boiler until the morning, thus still further ensuring the prompt restarting of the factory where continuous night and day work is not carried out. The transmission of heat from the products of combustion to the contained water in the boiler being not merely proportional to the temperature difference and inversely proportional to the plate thickness, but also depending upon the rate of circulation, it is not surprising to find that the introduction of the use of water-tube boilers into a sugar factory almost invariably promotes considerable fuel economy, and helps in a very striking manner towards the attainment of the abolition of the use of extraneous fuel to supplement the megass. This group of advantages explains why this class of boiler is steadily asserting itself, and is coming more and more into general use in all modern sugar factories. It is now necessary to notice the more suitable forms of generators of this kind which are available at the present day for such service.

Water-tube boilers are empirically separable into two main divisions: those which have their tubes fixed more nearly in a horizontal position, and those which have the same members placed more nearly in a vertical position. Both these divisions include generators constructed in some cases with straight and in others with curved tubes. Other conditions being equal, the straight tubes facilitate inspection and the rapid replacement of damaged units, more especially when the latter are of uniform length throughout the generator; the bent tubes promote simplicity of construction, and in extreme cases lend themselves more or less to the exigencies of unequal expansion and contraction. The advantages due to the more efficient transmission of heat through the thinner metallic heating surfaces are common to both types, and the benefits accruing from a brisk gas and water circulation have to be borne carefully

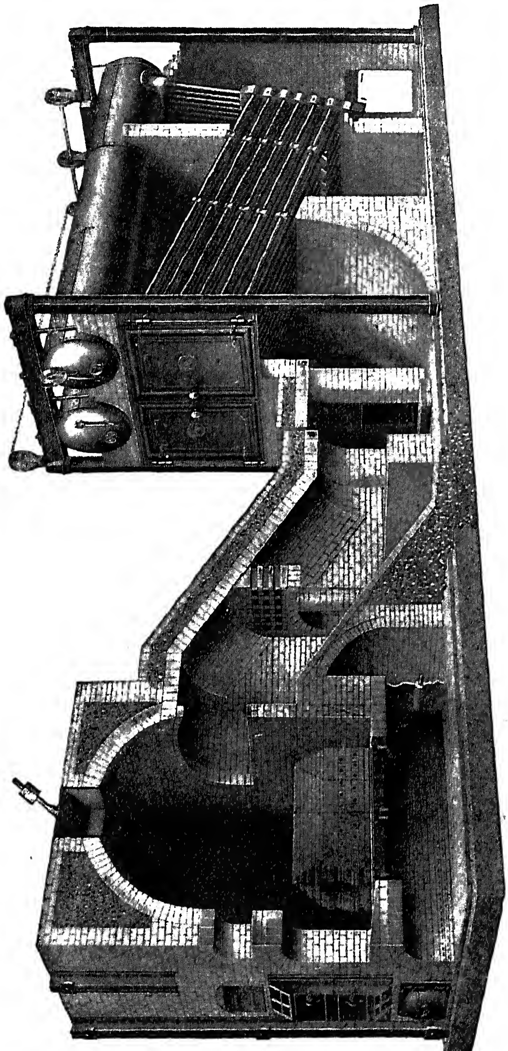


FIG. 216.—Water-tube boiler, fitted with straight-tubed heating surfaces of uniform length, placed at an angle of about 15°, and set with patent cold-blast furnace for burning green megass.

in mind in the design and construction of boilers of either division.

Two well-known types of these steam generators have already been referred to incidentally, and a reference to Fig. 209 will serve to explain the characteristic features of

a steam producer which was probably the earliest form of a modern water-tube boiler ever used upon a sugar estate. Fig. 216 shows yet another method of firing this apparatus with megass fuel, and illustrates the importance attached, as already mentioned, to complete combustion of the fuel before its products reach the boiler. This generator is so well known that it is unnecessary to enter into any detailed description of the characteristics of its form and construction. The illustrations already referred to are a sufficient exposition of the latter, serving as they do at the same time to explain the manner in which it is installed in its refractory chamber and the proper application of any form of megass furnace to boilers of this class.

Fig. 217 explains another type of boiler which of late years has come largely into use in sugar factories. It is in striking contrast to its predecessor, having curved tubes of varying length in place of straight tubes of uniform dimensions, and the bulk of its heating surfaces likewise stand in divided sections, and are placed in an almost vertical position. The chief object of this position and division is to attain as brisk and well defined a water circulation as possible, at the same time minimising the possibility of the lodgment of soot and ashes upon the exterior surfaces of the tubes, and the accumulation of scale and sediment within them. The curvature of the tubes, which is confined to a uniform radius throughout the boiler, promotes simplicity of construction, reducing the number of steam and water drums otherwise necessary, and avoiding any "cressing" of the drum-plates. Thus, any advantages due to the subdivision of the chief portion of the heating surface into four banks of tubes are obtained by the association of five uncressed drums, instead of eight cressed drums, which would be required with straight tubes. The larger-sized units of this generator usually require consider-

able head-room, and the brick walls of its refractory chamber-setting are, when compared with those of its predecessor, frequently of considerable height, necessitating increased thickness, coupled, in some cases possibly, with a slightly increased cost of instalment. Nevertheless, this apparent primary disadvantage ultimately constitutes one of the chief conveniences in the everyday work of the

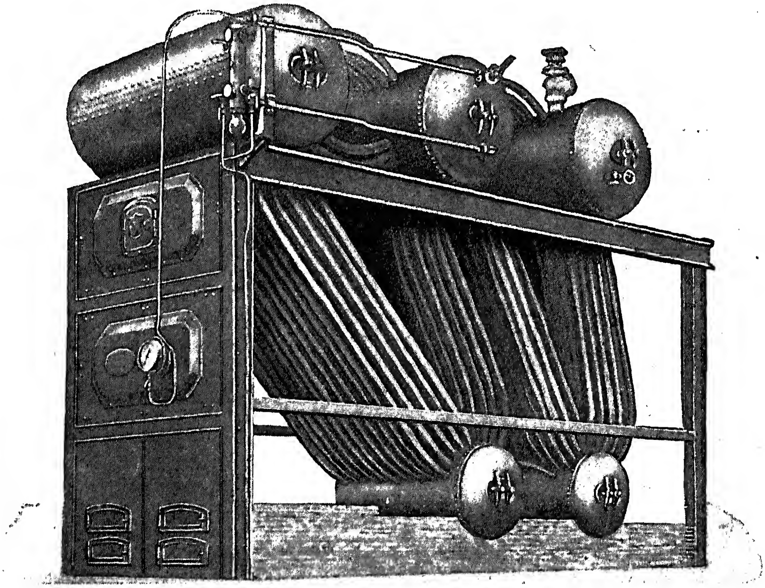


FIG. 217.—Water-tube boiler, fitted with curved-tubed heating surfaces placed more nearly in a vertical position.

generator, owing to the increased regenerative action of the boiler-setting, the importance of which has already been pointed out in connection with sugar factories worked intermittently. Fig. 206 has already shown this well-known steam raiser completely installed in its brickwork chamber, and the manner in which the megass furnace is attached to it. It also demonstrates the numerous "access" and "sooting" doors, which are invariably fixed in

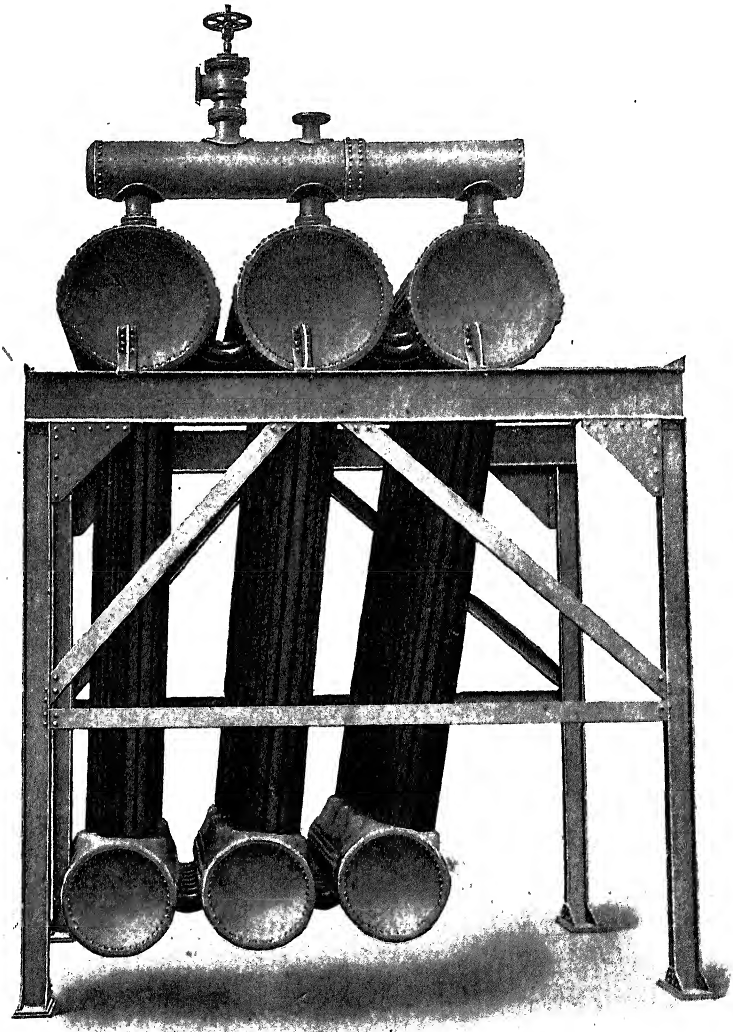


FIG. 218.—Water-tube boiler, fitted with straight-tubed heating surfaces placed more nearly in a vertical position.

the walls of the refractory setting, to facilitate examination, cleaning, and repairing of the tubes and flues.

This is not the place in which to discuss the respective merits of straight and bent tubes. Both sides of the question have been ably argued, and both forms have their warm advocates; and the controversy has too frequently been conducted with a ferocity which has spared neither opinions nor reputations, and has tended to smother a proper sense of the true proportion of the fitness of things. This never-ending discussion has led to the design, construction, and frequent use of a class of steam generator which seeks to meet the views and requirements of those of the disputants who prefer that the boiler heating surfaces shall be as straight, and be placed as vertically, as possible. Figs. 218 and 219 set forth the salient features of one type of this class of boiler. It is, in general effect, a collection of straight tubes in association with cressed and more numerous drums, in place of fewer uncressed drums and bent tubes; and in the case of the example now under consideration six drums are required for three banks of tubes. Fig. 218 shows the main constructional features of this generator. The cressing of the drum tube-plate is clearly seen, and a consultation of the next illustration, Fig. 219, will explain how the tubes are "nested" in adjacent groups instead of being placed in continuous straight rows. It will be noticed that in the top plate of each of the upper drums, directly above each nest, a suitably sized man-hole door is fixed, which, when removed, enables an inspection of the interior of every tube to be made conveniently, or permits of the ready removal and replacement of a defective member. As is usual with all generators of this class, the boiler stands supported by independent framing, and can be erected and hydraulically tested before any of the surrounding brickwork is built. Fig. 220 shows the boiler

standing within its refractory setting, to the right hand of which would be located one of the usual megass furnaces

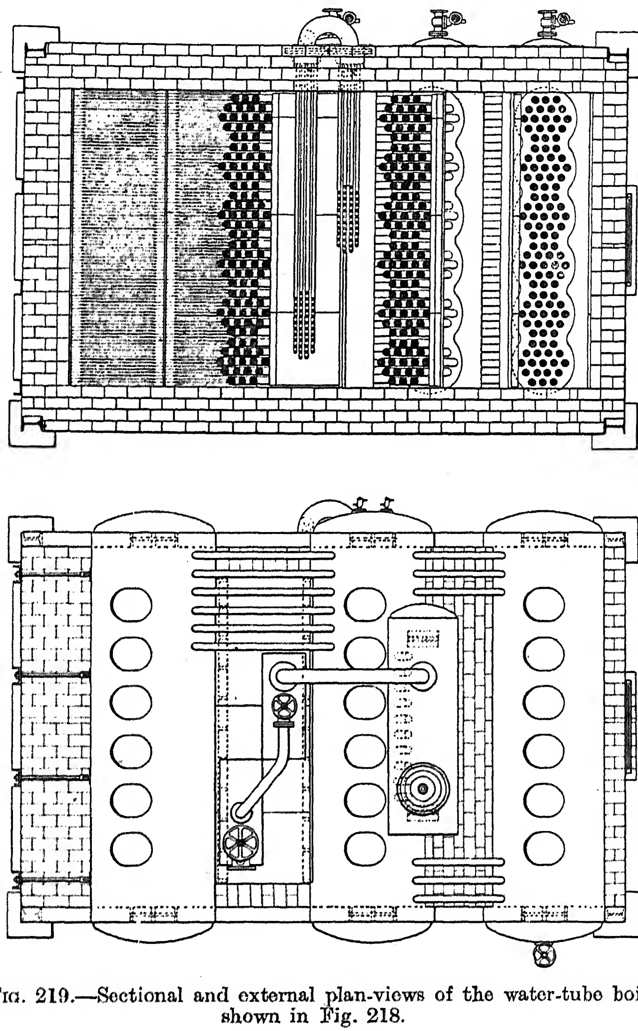


FIG. 219.—Sectional and external plan-views of the water-tube boiler shown in Fig. 218.

already described in the earlier portions of this chapter. The details, conditions of construction, and general characteristics of such setting are practically the same

as those referred to in connection with the previous example.

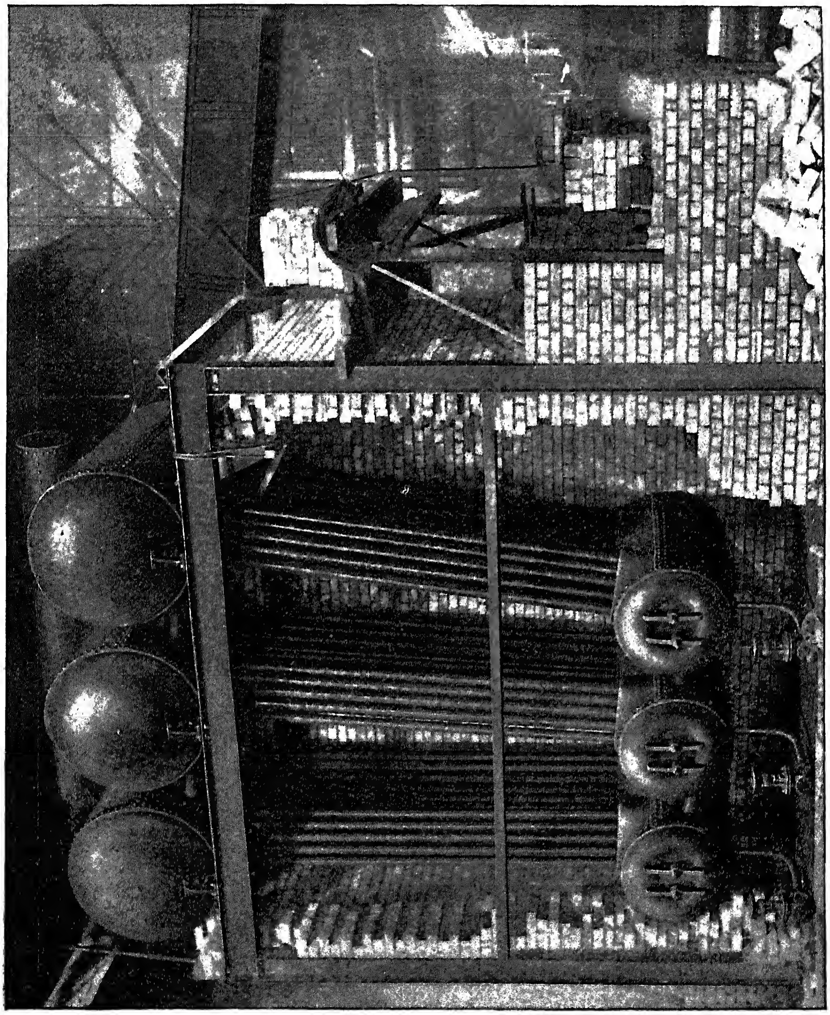


FIG. 220.—General sectional view of water-tube boiler seen in Figs. 218 and 219, showing how it is installed in its refractory brickwork setting.

Another boiler of the type with straight "nested" tubes is shown in Fig. 221. So far as the "nesting" of the tubes and the facilities for the examination, removal, and

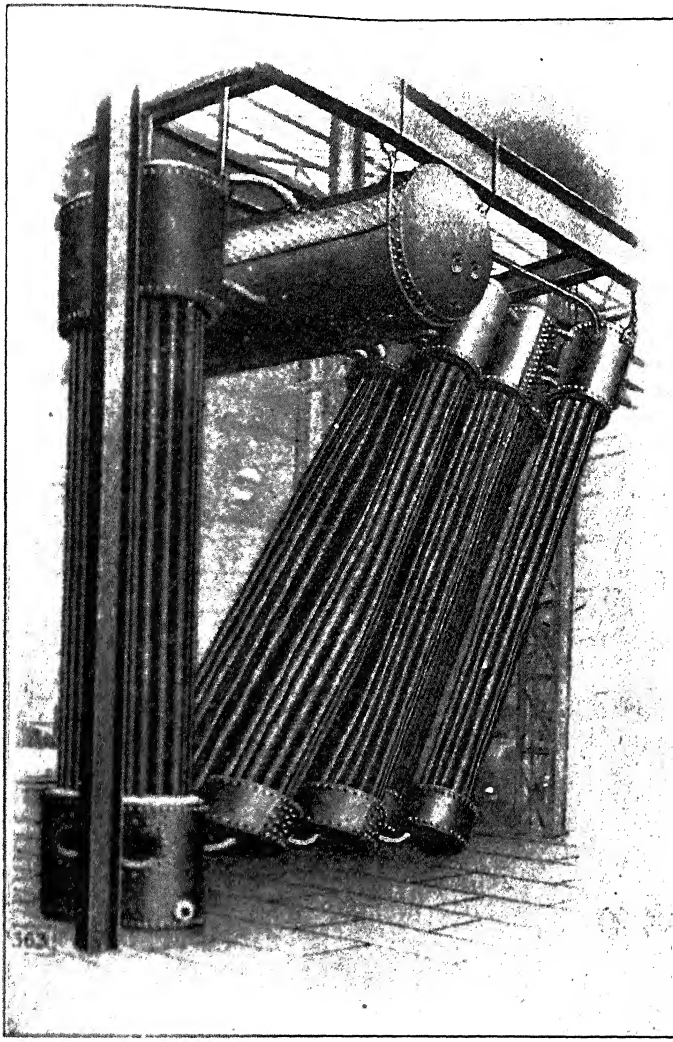


FIG. 221.—Water-tube boiler, fitted with straight-tubed heating surfaces associated with "headers" lying at the same more nearly vertical angle as the tubes.

replacement of defective units are concerned, this generator bears a close resemblance to those which have just been described. It embodies, however, a very distinctive feature, each nest of tubes being furnished with two short

and separate cylindrical steam and water drums, the centre lines of which lie at the same angle as the tubes by which they are connected. Several of these cylinders or "heads," placed side by side, and coupled to each other by means of short pipes, thus take the place of each of the larger

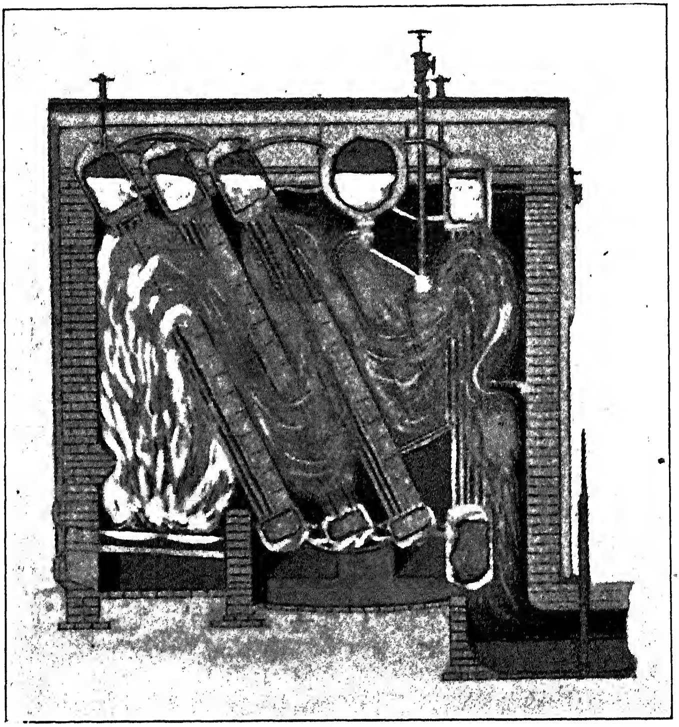


FIG. 222.—Sectional side elevation of the straight-tubed water-tube boiler seen in the preceding illustration, with superheater fixed between the third and fourth banks of tubes.

horizontal drums placed, in some of the other boilers, at right angles to the boiler tubes. Fig. 222 shows a generator of this description installed, as usual, within its non-conducting setting, and explains the path which the products of combustion take in their passage through the boiler, besides delineating the manner in which these act upon the heating

surface. In all boilers of the more vertical tube type the hot gases usually first flash upwards and along the first bank of tubes, then downwards along the second bank, and so on until they reach the flue leading to the chimney.

Figs. 223 and 224 show yet another straight-tubed water-tube boiler, which combines the salient features dis-

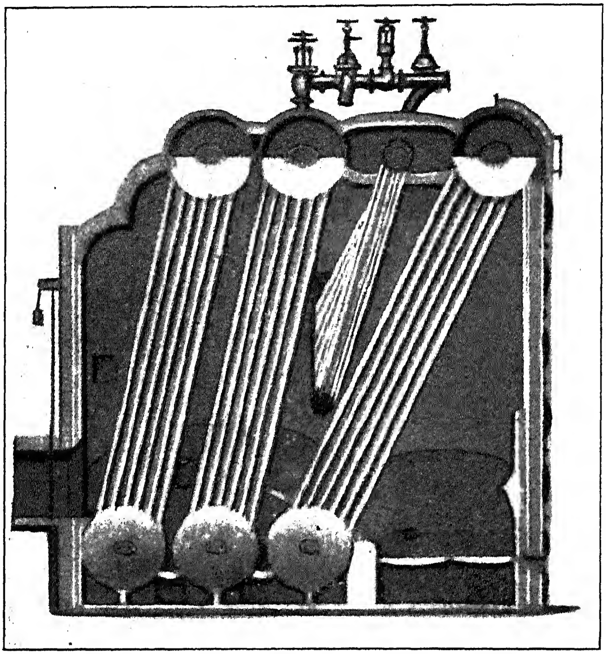


FIG. 223.—Straight-tubed water-tube boiler, fitted with tubes placed in straight rows instead of nests. Superheater shown in position between the two front banks of tubes.

tinguishing two diverse types already described. A special "landing" is formed by cressing the drum tube-plates for the reception of each of the tubes, any one of which, when required, can be withdrawn and replaced without the disturbance of sound units, no headroom above the upper drums being necessary for the purpose of tube renewals and removals. It will also be noticed that the tubes are not

nested, but are fixed in straight rows, an arrangement which will appeal with considerable force to many experts. The foregoing observations which have been made with reference to the installation and working of previous boilers of this class apply equally and generally also to

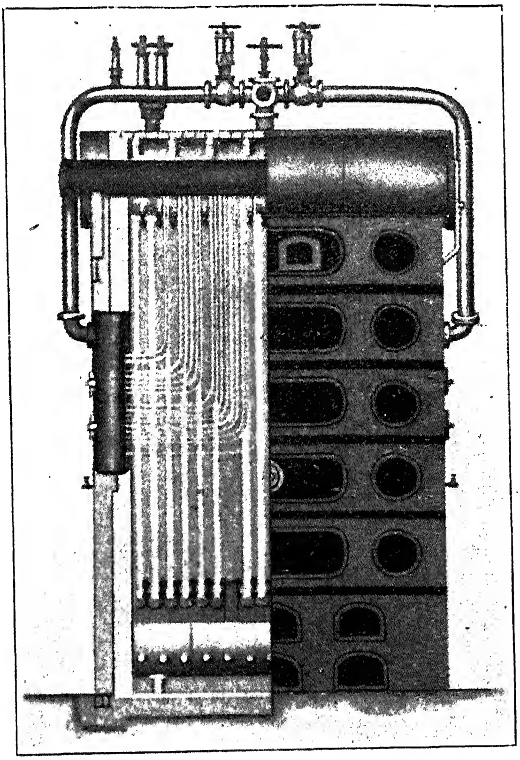


Fig. 224.—Cross-section and front elevation of the water-tube boiler and superheater shown in the preceding illustration.

this particular generator, and it will be perceived that their setting and mode of operation are almost identical.

Another type of water-tube boiler, which possesses special characteristic features, must now be noticed, as illustrating a class of steam generators which stand in a very distinctive group by themselves. The boiler proper

consists of a central vertical cylinder of considerable length, into which are fixed loop-like tubes of precisely uniform

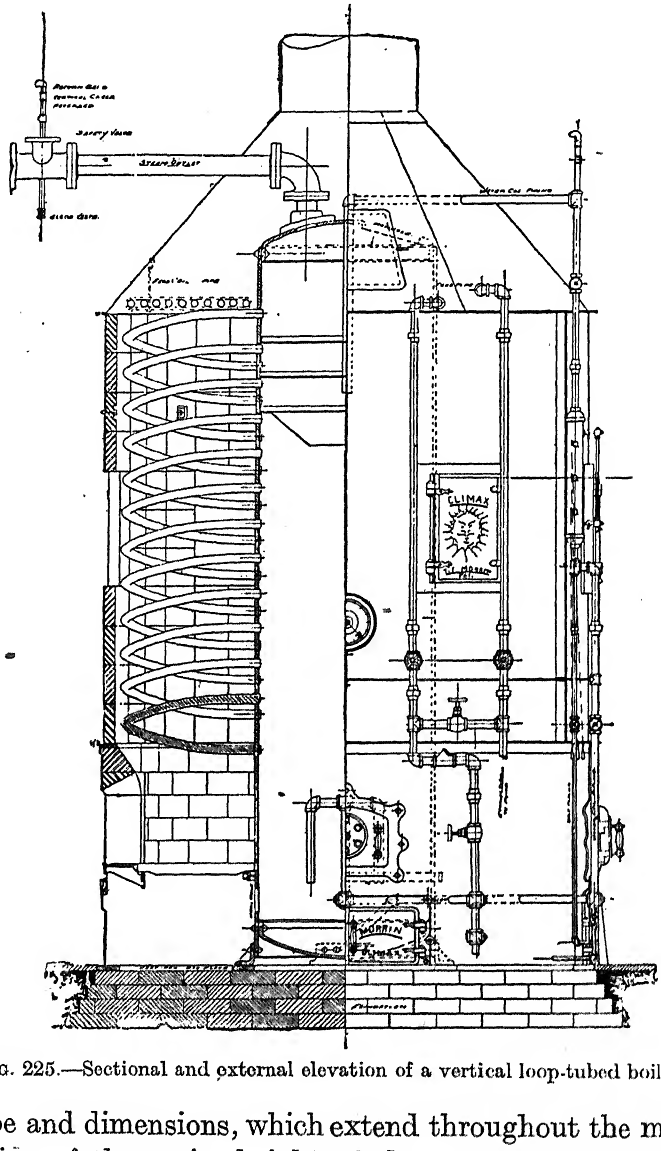


FIG. 225.—Sectional and external elevation of a vertical loop-tubed boiler.

shape and dimensions, which extend throughout the major portion of the entire height of the generator, as seen in

Figs. 225 and 226. The curved tubes form the principal portion of the heating surface, and a correct idea of the formation and disposition of them may be obtained by a careful examination of these illustrations. This system of tubes is enclosed in an outer cylindrical iron casing, bolted together in sections and lined with special firebricks, such casing and its lining taking the place of, and performing the functions fulfilled by, the rectangular settings just

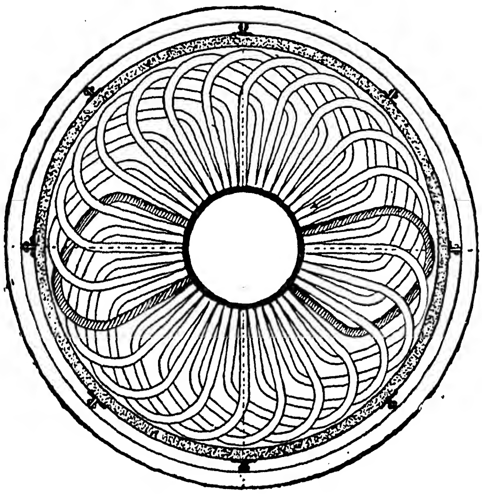


Fig. 226.—Sectional plan of the vertical loop-tubed boiler shown in the preceding illustration.

described in connection with the water-tube boilers already noticed. This casing is, as usual, furnished with numerous access-doors which facilitate the periodical cleansing of the heating surfaces, as well as the prompt replacement of defective tube units. A certain proportion of the bent tubes and the central cylinder are filled with water, and the heated products of combustion, first entering the lower end of the outer casing, pass upwards through the mass of tubes direct to the chimney which is placed at the upper end

of the external shell. Fig. 227 shows how two or more of these boilers may with advantage be worked in conjunction with one large furnace, the latter being approximately of the type of oven shown in Fig. 210.

A predecessor of this generator, aptly known as the Porcupine boiler, has also been very successfully used on

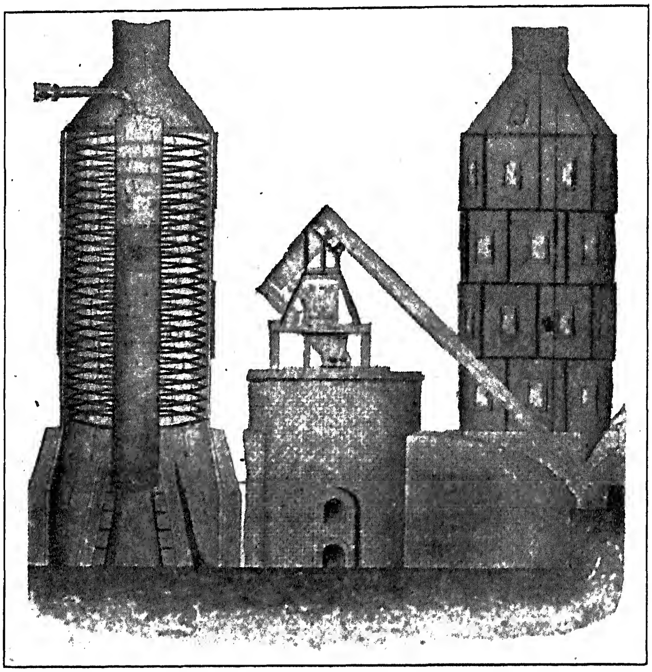


FIG. 227.—Two vertical loop-tubed boilers worked in connection with the same furnace.

sugar estates, and in its case the curved tubes, as above, were forestalled by very numerous and straight radial tubes of short length, as seen in Fig. 228. The outer ends of these tubes are closed, the inner and open ends, fixed in the central cylinder, having a free and full connection with the water contained in the latter. These units are enclosed in an outer refractory casing, or an iron and brick-lined shell, fitted in

the customary manner with a full complement of access-doors for the purposes of cleaning and repairs, the general outward appearance and working conditions of this boiler being very similar to those of the loop-tubed generator just described.

The more prominent types of steam generators applicable to the special requirements of a sugar estate, together with their special forms of external oven furnaces, have now been sufficiently described for the purpose of explaining their leading features. It only remains, therefore, to offer a few remarks concerning the particular class of fuel, the megass, which has to be used in conjunction with them. This megass, as it is brought to the furnaces from the mills, consists practically of the whole of the fibre and woody matter of the cane in a finely-divided condition, together with such juice as has escaped expression by the mills. When maceration has been employed, there will also be a certain amount of outside water due to this process.

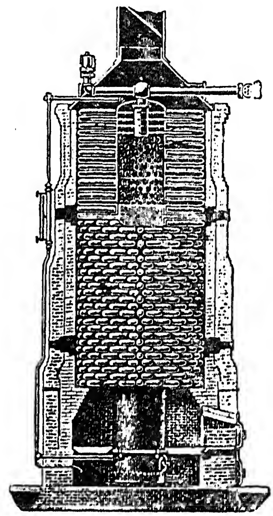


Fig. 228.—Porcupine boiler.

The relative proportions of the constituents of megass depend naturally upon the nature of the mill work performed. For the sake of example two illustrations may be taken, the one (A) in which dry double-crushing has been effected, and the other (B) in which full extraction by an eleven-roll mill plant with 20 per cent. maceration has been carried out, the cane in each instance being a normal cane with 12 per cent. fibre, as has been taken throughout in this

work. In these instances the composition of the megass may be somewhere in the neighbourhood of:—

	A.	B.
Water	49	52
Sugar	$7\frac{1}{2}$	4
Fibre	42	$42\frac{3}{4}$
Other organic matter and ash	$1\frac{1}{2}$	$1\frac{1}{4}$
	100	100

To give an entirely accurate figure for the fuel value of megass satisfactorily, by calculation, is not possible. Although the fibre of the cells has the same ultimate chemical composition as that of the vascular bundles, there is great reason to believe that there is a difference in the fuel value under actual combustion. The fuel value of the fibre as a whole would, therefore, vary according to the relative proportions. Again, the nature of the mineral matter present is an important factor in combustion. A megass which contains a large proportion of easily fusible salts, such as occurs with rank or immature canes, burns with difficulty on account of the fusion of the saline constituents clogging the fuel and interfering with the combustion of the fibre. Again, the physical condition of the megass has an important bearing on its fuel value—the coarser the nature, the better being its form for combustion. A megass, therefore, which may present an apparently suitable chemical composition as regards water and fibre for a good heat supply, may yet, from either of the above causes, give disappointing furnace results.

In calculating the fuel value of megass it is customary to take as a basis the thermal power of carbon in the form in which it exists in wood. Although recent experimental determinations of the heat value of pure cellulose and sugar give results somewhat higher than those thus calculated,

it has been thought advisable to adhere to the former system, as the slightly lower results thus afforded are probably, for reasons already stated, more representative of the actual position.

The gross calorific value of megass of the above composition will therefore be

A.	B.
3142 thermal units.	2911 thermal units.

And when the heat required to evaporate the contained and associated water is deducted, as well as that which is lost in the waste gases, there remains available for steam-raising purposes

A.	B.
2202 thermal units.	1940 thermal units.

In this calculation no allowance is made for the combustion value of the small quantities of uncrystallisable sugar and other organic matters present, this being considered as compensating for loss by radiation.

With feed water at 160° Fahr., and a boiler pressure of 80 lbs. on the square inch, there would thus be generated as the result of the combustion of 1 lb. of megass steam equivalent to the evaporation of

A.	B.
2·10 lbs. water.	1·88 lbs. water.

As has been already stated, the bare chemical analysis does not always indicate the fuel value of the megass. The above, however, may be taken as affording a fair indication of the quantity of steam which would be generated with perfect combustion. In practice, however, it is not advisable to aim at complete combustion of the carbon, as to do so a quantity of air has to be introduced which, by carrying away a greater amount of heat in the form of waste

gases, more than counterbalances the advantage gained by complete oxidation of the carbon. What is aimed at, therefore, is so to adjust the air-supply as to have a minimum of carbonic oxide or incompletely oxidised carbon present, with as small as possible excess of air. This is generally obtained by keeping the air-supply rather below twice the quantity theoretically required. Owing, therefore, to a small quantity of carbon not being, for economic reasons, completely burnt, the above figures, which are calculated on the basis of complete combustion, are on the high side. On a working basis, results are usually obtained agreeing with the above figures after deducting 10 per cent. from them.

The scientific control of the boiler-house occupies the chemist as well as the engineer. From time to time joint observations have to be made as to what steam is being generated in relation to the quantity of megass used. In this connection the duty devolves on the engineer of obtaining accurate records of the weight of megass and feed-water used, and of registering at regular intervals during the period of observation the steam pressures, the temperatures of furnace and flues, the amount of draught, direction of wind, and general atmospheric conditions—in fact, to make a note of any point bearing on the consideration of the results. To the chemist is assigned the analysis of the megass going to the furnace, which should include the estimation of the amount of crystallisable and uncrystallisable sugars, together with the proportion of fibre, water, other organic matter and salts, and of the flue gases escaping up the chimney in regard to the oxygen, nitrogen, carbonic acid, and carbonic oxide which they contain.

The observation, which should extend over several hours, being concluded, data for drawing up the following statement are obtained:—

Dr.		Cr.	
Heat units in megass going to furnace		Heat units in steam generated	
		,, ,, lost by imperfect combustion ..	
		,, ,, lost by radiation, etc.	
	——		——

The proportion of the gross heat value of the megass which is recovered in the form of steam varies between 60 and 70 per cent. according to the proportion of water present, the latter being an important factor, as the amount of heat units carried away by the vapour representing the water in the fuel is a heavy item.

Too much stress cannot be laid on the value of systematic scientific control in connection with the boiler-house. Nowadays, when canes of many different descriptions are cultivated on the same estate, there are enormous variations in the fuel value of the megass, and a justifiable fuel account may exist which may be the cause of considerable unnecessary friction between manager and engineer. As already mentioned, the mere analysis of the megass is not sufficient to settle the point, and the only crucial test is the actual work being done by the furnaces and boilers carefully considered in conjunction with the analysis of the particular class of fuel in use at a given time. Again, it may be found that the behaviour of the boiler range is satisfactory, and that a full amount of steam is being given for the quantity of megass used, thus indicating that the cause of high fuel consumption must be sought elsewhere. These are special conditions which make the observations of value. But there is another and extremely important function which they fulfil, viz., the control which they maintain over the efficiency of the boilers and furnaces, whereby any

deficiency in working can be at once ascertained and corrected. In this way, by frequent tests and continuous supervision, the last available pound of heat energy is obtained from the megass.

As a conclusion to the above references to the subject of the generation of steam through the agency of megass fuel, it is very desirable once again to emphasise the fact that theoretical calculations invariably show that as a general rule the megass fuel should suffice for the full requirements of an ample steam supply for any well-arranged up-to-date factory, though an excessive percentage of low-grade canes may, of course, upset the general run of such calculations, whilst the presence of 10 per cent. fibre in the canes should ensure satisfactory results so far as sugar manufacture proper is concerned. It is much easier to waste steam than to raise it, and there is little doubt that in many cases megass furnaces, so far as they themselves are concerned, are already working with sufficient efficiency to obviate the additional employment of extraneous fuel, although this much desired result does not actually accompany their efficient performances. The fact remains that the steam so carefully provided by the use of every conceivable appliance, coupled with due supervision, is unwittingly wasted in the various factory processes. The heating of the cold juice, the maintenance of acquired temperatures, coupled with the requirements of the processes of clarification, concentration and crystallisation, afford wide opportunities for the careful prevention of the waste of direct steam, such waste being the frequent cause of disappointments which are often wrongly charged to the account of the work of the boiler-house. It is an important necessity to generate steam efficiently and economically; it is equally important to most carefully supervise its subsequent expenditure in the various factory processes;

and attention is again called to the remarks in Chapters III., V., VII. and X. that bear on this all-important subject.

In certain of the more advanced sugar-producing centres "economisers" are used with excellent results. Fig. 228A gives a sufficient idea of these well-known auxiliaries which economise through the utilisation of the waste heat of the flue gases on their way to the chimney, and constitute themselves a substantial and valuable addition to the steam-producing capabilities of the boiler-house, more especially in cases in which a mechanical

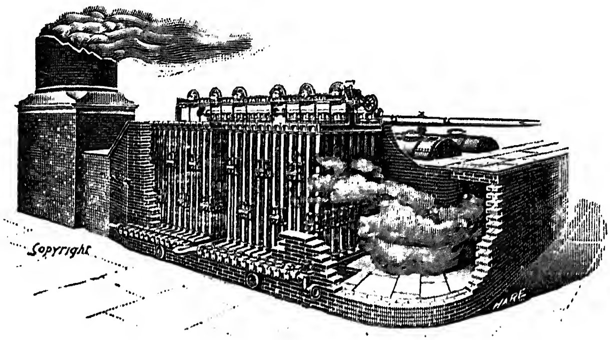


FIG. 228A.—Standard Economiser, for utilising waste heat of furnace flue-gases.

draught is employed, when the concomitant employment of an economiser should invariably be considered and adopted if possible.

It will not be out of place at this stage to touch briefly upon the question of the electrification of sugar factories, and, nowadays, the distinctive terms "steam driven factory" and "electrically driven factory" are constantly observed in connection with most industries.

As a matter of actual fact, both these systems rely upon the use of steam as the fundamental agent in the performance of the work of the entire factory, and in sugar manufacture the megass coming from the cane-mills ought, in either case, to be the only fuel used.

Having employed this megass, as fuel, to the best advantage, and having thus raised the maximum possible amount of steam in the boiler-house, the question arises as to the most advantageous disposal of this all-important steam-supply, in order to make absolutely sure that no extraneous fuel, other than megass, will have to be used for steam-raising purposes.

Turning attention for the moment to the steam requirements of any given sugar factory, we realise, in the first place, that the steam-supply to this factory may be considered under two sections: (*a*) The steam required to actuate the steam-engines, or electric generators, and (*b*) the steam necessary for the purposes of treating the cane juice and manufacturing it into sugar; and, upon a further examination of these two divisions, we realise that the engines, or motors, will, according to circumstances, absorb about from 5 per cent. to 14 per cent. of the total available heat units, whilst the manufacturing section will use up the balance of the total steam-supply.

This empirical division does not, however, exhaust all the surroundings of the question, for when steam-engines are employed in place of electric motors, at least about three to four times as much steam-piping has to be installed in a "steam driven factory" as would be required in an "electrically driven factory," and the serious loss due to radiation of heat is intensified, to say nothing of the more obstructive and inconvenient character of these conduits as compared with the much simpler installation of electric cables. At the same time it also becomes evident that the major portion of steam economy, due to the use of electricity, is chiefly confined to the surroundings of the minor section of the steam requirements of a sugar factory. Nevertheless, there is a reduction of the total factory manufacturing expenses from economies in labour, lubricants,

and special conveniences, coupled with a certainty that a saving of steam may be effected by the use of electricity, owing to the decreased loss of heat through radiation and steam-condensation in connection with the steam-engine cylinders and the large amount of steam-piping installed throughout a steam-driven factory, as well as to the greater economy and efficiency realised through the generation and employment of an electric current.

In preparing the plans for a sugar factory, the principal requirements that have first to be considered at the very outset are those relative to the question of the manufacture itself, and these requirements will chiefly determine the general arrangement and outlay of the entire installation which, at most, will be affected to but a slight extent should electric motors be used in preference to steam engines, and Plan 228B illustrates these considerations.

When electricity is employed, no high-pressure steam-main will enter the factory proper. This, in greatly reduced proportions, will, in such case, be led instead to an adjacent power-house accommodating the dynamo and its attached steam-engine; and then a short range of exhaust-steam piping will convey the waste steam from this engine for use in adjacent juice heaters, in order to ensure maximum steam economy.

The evaporators and vacuum pans will be served with steam direct from the boiler-house at reduced pressures, and this single and much-curtailed range of piping, of comparatively moderate proportions, is the only steam-pipe that will enter an electrified factory.

In many cases in which the percentage of fibre in the canes is unusually low, owing to the probable presence of a large proportion of seedling canes, the employment of electricity may prove a turning-point, and be the best

means available for the avoidance of the use of extraneous fuel.

Great attention is being paid at the present time to this question of electrification, and a large number of most interesting figures are being frequently published with reference to this important subject, and in the near future it is expected that it will be possible to present to the sugar-public well-established data concerning the performances of completely electrified modern factories that have established their anticipated superiority, and that have, from their very inception, been designed and constructed to work throughout with the fullest possible assistance of an electric current.

CHAPTER XII

THE BY-PRODUCTS OF SUGAR

In most industries, after the acquirement of the particular product the securing of which is aimed at, a residue almost invariably remains which cannot be realised in the marketable form assumed by the main object of such industries. In the case of the manufacture of cane sugar, this residue, or offal-crop, as it is sometimes termed, is chiefly found in the molasses which is separated from the sugar crystals by the action of the centrifugals. At the same time the mud from the filter presses, the refuse from the distillery, as well as the megass ashes from the boiler furnaces, should not be disregarded. All of these substances may, in the first place, be utilised to a greater or lesser extent by their direct return to the land as manure. In this way some 50 per cent. and upwards of the constituents of plant food, abstracted during the growth of the canes, may be returned to the cane-fields, and the productiveness of the latter maintained, over very considerable periods of time, independently of the application of extraneous manures.

Another use to which molasses is sometimes put is augmentation of the fuel supply of the factory. It, however, cannot be satisfactorily burnt by itself, as the contained salts are apt to fuse, and to form a cake long before complete combustion has been effected. It is therefore more generally utilised in megass furnaces, in conjunction with the megass, the molasses being sprayed on to the latter as it enters the furnace; and in this manner 4·5 lbs.

of molasses, if efficiently burnt, are found to do about as much work as 1 lb. of coal.

Great attention is, however, universally paid nowadays to the question of the manufacture of by-products with a view to promote the further profitable utilisation of manipulative remainders, and to place them upon the market in various forms, for different purposes, thereby increasing the remunerative results obtained from any given process. In this direction the manufacture of alcohol, in the well-known form of rum, occupies, and has long held, a prominent position. This by-product has been in evidence from the earliest times of the West Indian sugar, industry. From the necessarily imperfect manufacture resulting from the elementary appliances then in use in the sugar-boiling house, a considerable amount of the juice, in the form of molasses, skimmings, etc., remained after the sugar was made, and the manufacture of rum thus occupied a very prominent position in the economy of a sugar estate. Not only was it shipped for consumption in the Mother Country, but it also constituted the principal article of drink in the country in which it was made. Gradually, however, as the processes of sugar manufacture improved, the amount and quality of the spirit made per ton of sugar diminished. It ceased to be the drink of the better classes in the country of origin, although it still remains that of the peasantry. In Jamaica, from economic reasons, it continues to be an extremely valuable and important asset, and, in order that the old characteristics of the rum turned out there may be maintained, and a consequent high price secured, much of the juice in the form of molasses and skimmings is devoted to this object, which in other sugar-making countries is utilised in the manufacture of sugar crystals.

Although in some few instances rum distilleries are

institutions separate from the sugar factories, the distillation of rum is, as a general rule, carried on as a part and parcel of the treatment of the cane, and goes on simultaneously and in conjunction with sugar-making.

The manufacture of rum is divided into two branches, fermentation and distillation, the first dealing with the transformation of the sugar of the molasses, etc., into alcohol, the second with the separation of the alcohol from the fermented liquor.

As mentioned above, the products which are used in the manufacture of rum, save in the case of spirit of the Jamaica class, are molasses from which as much sugar as possible has been extracted, coupled with such washings of the factory vessels and appliances as cannot be utilised for sugar purposes.

The transformation of sugar into alcohol is carried out by the agency of a microscopic vegetable organism, termed the yeast plant, belonging to the family of *Saccharomyces*. A large number of varieties of yeast exist, each of which is supposed to have its special influence on the flavour of spirit. This difference in flavour, however, must be attributed to organisms associated with the yeast rather than to the yeast itself. It is worthy of remark in this connection that the yeast operating in the fermentation of high-flavoured Jamaica rums is of a distinctly different character to that observed in the manufacture of normal rum.

Unlike the practice in temperate countries, where prepared yeast is added for each fermentation, in the manufacture of rum, natural yeast, *i.e.* the yeast adhering to the cane plant or existent in the atmosphere, is utilised. The appearance which this yeast ordinarily shows in rum washes is seen in Fig. 229, where the small oval and circular cells of the normal yeast plant are seen. The plant as a rule

propagates by budding—that is to say, as the plant grows a bud appears on the parent cell, which eventually breaks off and starts a separate existence. During the growth of the yeast plant the cane sugar is first of all converted into uncrystallisable sugar, and then into carbonic acid gas and alcohol. A considerable rise of temperature takes place during fermentation, varying with the rate of fermentation

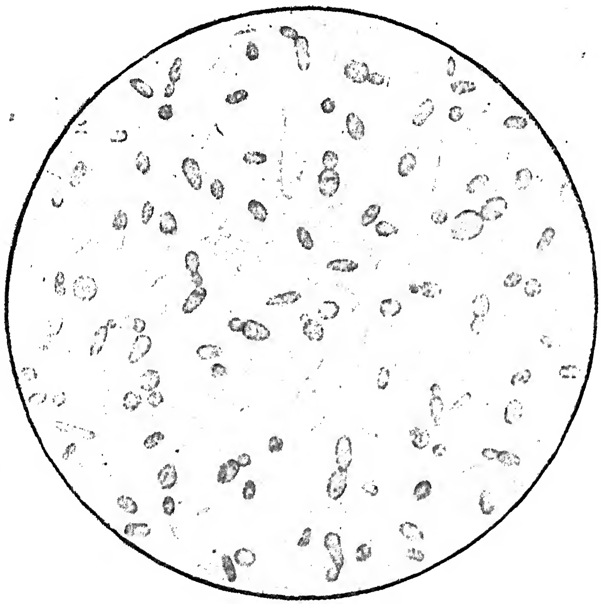


Fig. 229.—Microscopic appearance of yeast cells, showing also putrefactive bacteria.

and the size of the fermenting vessels. Starting with an initial temperature of 84° Fahr., it is quite possible with the rapid fermentation and large fermenting vats of the Demerara method for a temperature of 110° Fahr. to be arrived at during the process.

Although rum is alcohol, alcohol is not necessarily rum, the flavour of the latter product arising from the presence of bodies, known as ethers, which impart the distinctive

.r, and considerably augment the stimulating pro-
s. These ethers are produced as the result of the
of various bacteria, which operate at the same time
yeast, and give rise to various organic acids, such as
and butyric acid, which yield the corresponding
pound" ethers by their combination with alcohol.
bodies remain with the spirit during distillation
ling to the degree of their original presence, and to
tent to which the spirit is purified in the process. As
acteria which produce the distinctive flavouring
s are associated with the conditions under which the
-cane is grown, the characteristic flavour of true rum
ly obtained when the fermentation of molasses is
d on in sugar-cane countries. Putrefactive bacteria
so generally present, but their presence is objection-
and they should be kept under as much as possible.
microscopic appearance is also shown in Fig. 229.
ermentations are conducted in what are known as
or-lofts" or "wash-houses." A typical structure is
at C, in Fig. 230, which gives a plant and elevation of
plete rum distillery. B is the wash-mixing tank, in
the liquor is prepared for fermentation. At C are
hirty fermenting vats, to which this wash is next
ferred, via the pump H and the gutters R, and in
it ferments. D is the fermented wash suction tank,
which the wash runs, after fermentation, on its way
still. S, S, are the gutters by means of which it has
conveyed from the vats to the tank. L and M are
ctively the "rectifier" and "analyser" columns of
Coffey Still, to which the fermented wash next pro-
via the pump K, and in which the process of distilla-
s conducted. G is the "refrigerating tank" in which
lcoholic vapour is condensed as it passes from the
y Still to the "safe" N. A, A, are the spirit receivers,

in which the rum is stored until such time as it is drawn off into casks for shipment. O and P are the steam boiler and its attached chimney, whence steam is procured for operating the still and driving the various pumps used in the distillery. E is the hot "feints" vessel, and F the cold "feints" receiver, more precise reference to which will be made in due course.

The molasses, washings, and water are run into the mixing cistern in the proper proportions, and thoroughly mixed, with the aid of the mechanical mixer shown there. By the careful adjustment of the supply of the several constituents, a constant density of 1·060 is obtained. This density has been generally adopted where dunder, or the exhausted wash after distillation, is not used, as it is found to be the one which gives a maximum yield of alcohol in proportion to the sugar present, the larger proportion of spirit formed from wash of a greater sugar content than that corresponding to this density interfering with the growth and action of the yeast.

The vats, which have been carefully cleaned after the last charge, are then filled with the wash. In order to secure a sufficient degree of acidity to render the wash unsuited to the development of putrefactive bacteria, the absence of which from the wash is highly desirable, it is customary to add sulphuric acid in the proportion of somewhere about one gallon of the strong acid to 1000 gallons of wash, and, where a rapid fermentation is aimed at, sulphate of ammonia to the extent of 10 lbs. per 1000 gallons is added. The presence of the two latter brings up the specific gravity of the wash to 1·0615.

The wash is then left to ferment, which it does by the development of yeast acquired from the air or the vat, and in two or three days if sulphate of ammonia is used, or in seven or eight days if this agent is omitted, the alcoholic

fermentation is complete, and the contents of the vat begin to cool. Co-existent with the alcoholic fermentation bacterial action goes on, resulting in the production of acetic, butyric, and other acids, which, by forming compounds with the alcohol—ethers, or " esters " as compound ethers are now termed—impart the necessary flavour to the alcohol when distilled. At this stage acetic acid fermentation sets in rapidly, and unless the wash is promptly removed to the still considerable loss of spirit arises from this cause. By this method of fermentation a rum is obtained which, although not possessing high ester contents, constitutes a clean and sound spirit.

Another system of fermentation is that used in the manufacture of high-class rum of the Jamaica type. This, so far as exported rum is concerned, is practically confined entirely to Jamaica. In it the production of sugar is sacrificed to the exigencies of the rum manufacture. The molasses used is of high quality, and in addition a considerable amount of juice in the form of skimmings, and sometimes raw as it comes from the mill, is used. Dunder, or spent wash, is also utilised, the dead yeast in it, apart from other considerations, contributing a considerable supply of nitrogenous food for the growth of the fresh yeast. Fermentation is prolonged to encourage the production of butyric acid, the ferment of which is anaerobic, or light-abhorring. Thus the fermentation is conducted in the dark as much as possible, and every means taken to secure the development of the flavouring bacteria. The initial density of the wash is higher than with the preceding process, the dunder present, *per se*, contributing largely to the non-sugar contents.

As already mentioned, a distinctive feature in the Jamaica " washes " is the presence of a kind of yeast which has not hitherto been noticed elsewhere. The cell of this

variety is elongated, and instead of propagating itself by "budding" does so by "fission" or a splitting up of the cell. This variety is capable of growth in wash acid enough to put a stop to the development of the budding variety, and, as has been already pointed out, the flavour of rum depends upon the production of certain organic acids, this property is a powerful factor in the manufacture of Jamaica rum. Further, butyric acid, which, in the form of butyric ether, plays an important part in rum flavour, is

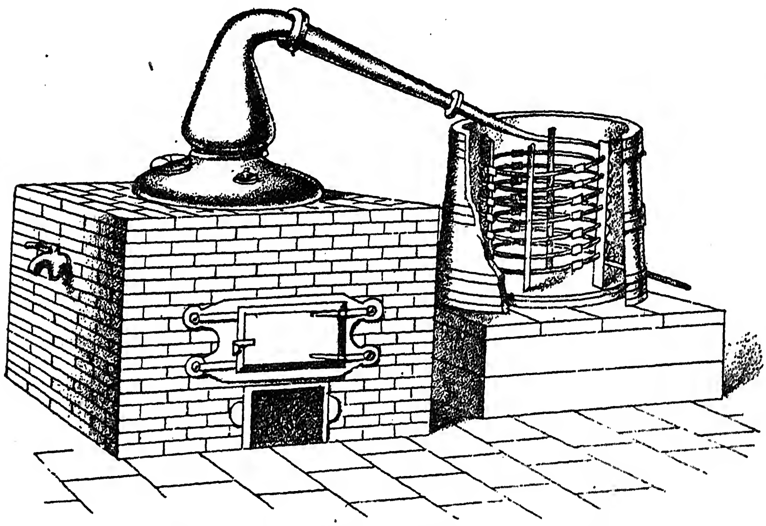


FIG. 231.—General view of a simple form of still.

extremely antagonistic to yeast development, but much more so to the bud variety than to the fission yeast.

The fermentation of the wash having been completed, it is transferred to the still. A still consists primarily of two parts—a vessel in which the wash is heated, and a pipe surrounded by water connected with the top of the wash vessel, through which the distilled vapours pass and are condensed. A simple process of this description, however, produces a spirit of extremely low strength. Fig. 231

shows an early form of such a still. In order to raise the strength, redistillation has to be carried out, the weak spirit in this instance occupying the place of the wash.

With the view of obtaining the stronger spirit in one distillation, a compound still is used, formed of two vessels or kettles. In this the "goose-neck" of the first leads into the bottom of the second and smaller kettle. The wash is placed in the first body, and the low wines or weak spirit from the first distillation is added to the second. The alcohol and vapour from the first vessel is condensed in the second, and in this way boil the contents which already contain alcohol. The vapour which first comes over from this is strongly alcoholic, and on being condensed yields a strong spirit. This, termed "high wines," is collected in a special receiver, and as the spirit being distilled becomes weaker it is run off into a separate vessel. When the last of the alcohol has been boiled out of the second vessel, a point which follows the exhaustion of the wash in the first, the distillation is stopped, the low wines thus obtained forming the charge of the second vessel in the next distillation. The wash is generally heated by an open fire under the copper kettle, although steam is sometimes used. By duplicating the second vessel, or "retort," a rum of considerable strength can be turned out—upwards of 40° O.P.

The double retort type of still is much used in Jamaica, and is shown in Fig. 232. The first and larger vessel is here seen mounted in a brickwork setting, which contains the fire-grate. The two succeeding and smaller vessels, or retorts, may stand, as shown, upon a timber framework, and the alcoholic vapour from the third and smallest vessel of the series passes through its attached "goose-neck" into the copper coil of the refrigerator vat or tank, where it is condensed by the cold water contained in it, the

circulation being maintained by the admission of a continuous stream of fresh water entering at the bottom of the tank, the heated water overflowing through the upper outlet.

A modification of this form of still is in use in Demerara. In this (see Fig. 233) only one retort is used, the further rectification being carried out by means of a multitubular rectifier placed on the top of the retort. The copper "kettle" also is usually replaced by a stout greenheart vat,

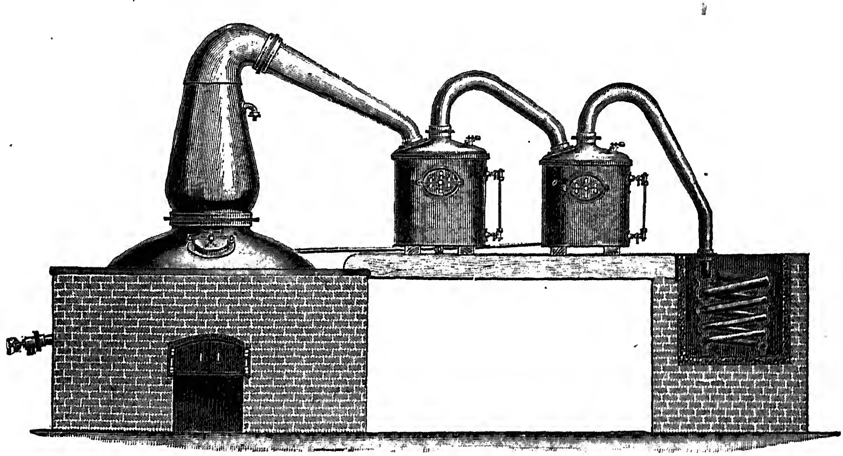
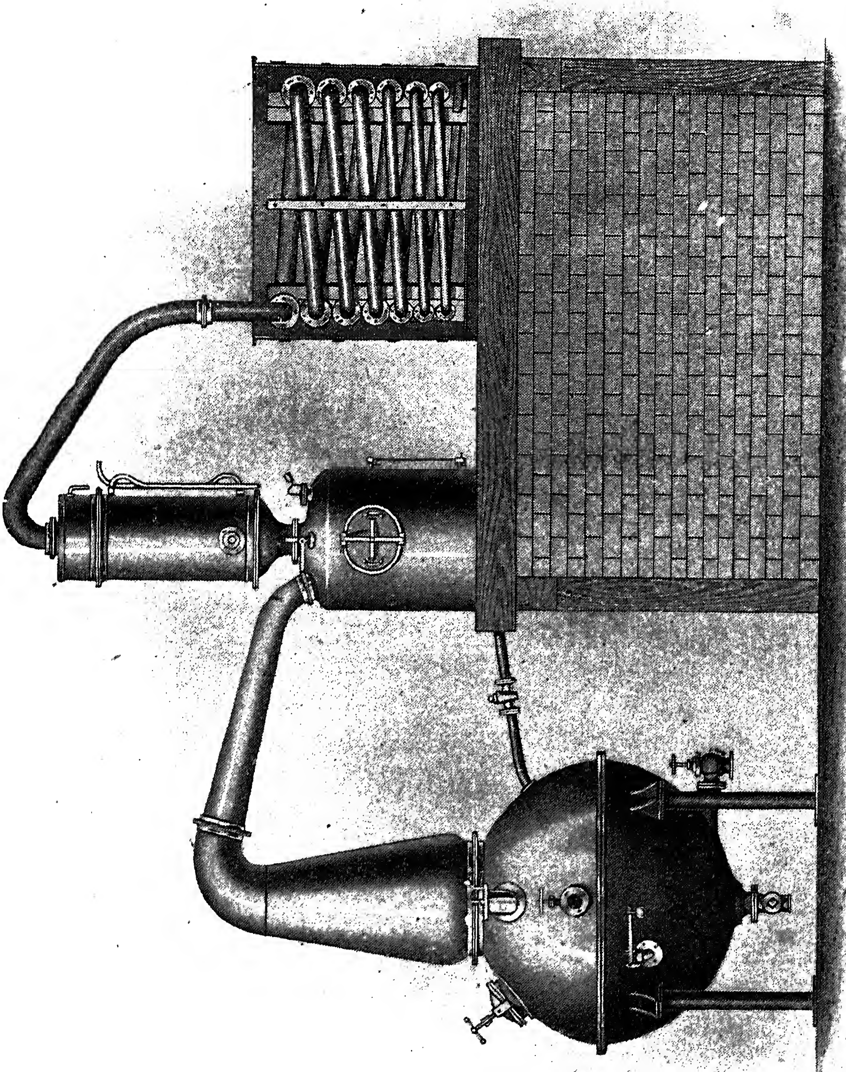


Fig. 232.—Elevation of a pot-still, with double retorts, used in the manufacture of Jamaica rum.

and the wash is heated by steam, either through the agency of a closed coil or open jet.

The vat, or kettle, having been charged with the wash, and the retort with the low wines from the previous distillation, steam is turned on to the kettle. When the contents of the retort are raised to the boiling-point by the vapour coming over from the still, the comparatively weak alcoholic vapours thus produced rise through the rectifier tubes. Here their temperature is lowered by the cooling effect of the water in contact with the outside of the tubes of



G. 233.—Elevation of a steam pot-still, with single retort and multitubular rectifier. Refrigerator tank shown in section.

the rectifier. This brings about a condensation of a considerable portion of the water vapour, which, having a condensing point higher than that of alcohol vapour, falls back into the retort. The vapour, therefore, which passes on is much stronger in alcohol than the vapour entering the rectifier, and, as it passes through the worm, is condensed, and flows from the delivery spout in the form of spirit. At the start the strength obtained is comparatively low, but it soon rises to 54° O.P. or thereabouts, gradually declining from this point. When the strength falls to about 42° O.P. the spirit is cut, and its flow is diverted from the "high wines" receiver to the "low wines" receiver. When the spirit is extracted from both wash in the still and low wines in the retort, which is denoted by a sudden milky appearance in the flow and in the behaviour of the cutting bubble used for the purpose, steam is turned off and the operation concluded. This particular form of still may, if the "kettle" is of copper, and if more convenient, be worked by means of a fire in place of steam, as shown in Fig. 234.

As in the manufacture of sugar, so also in that of rum, a certain amount of fuel, of some description or another, has to be consumed. When any of the forms of stills described above are used, this consumption may approximately be set down as amounting to some 10 cwts. of coal per 105 gallons of rum, standing at, say, 42° O.P. As it is desirable to keep this fuel account within the lowest reasonable limits practicable, various devices are always being sought whereby such reduction can be secured. The alcoholic strength of the fermented wash, the exigencies of rum manufacture, and the importance of an unimpaired maintenance of the leading and most valued characteristics of the rum, have, however, a special bearing on this question. In earlier chapters on the concentration or evaporation of cane juice, the general treatment of all

questions of steam or fuel economy of this character has already been explained; and in the employment of a simple rum still, such as is seen in Fig. 231, the fuel or steam used

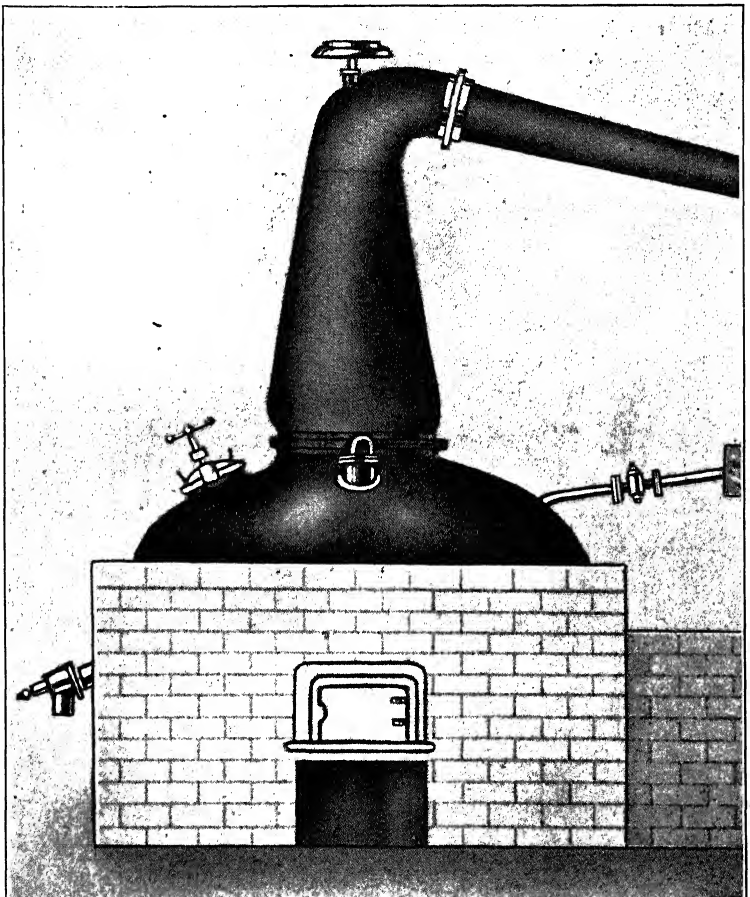


FIG. 234.—Elevation of a pot-still, worked by fire instead of steam. Identical in all other respects with the still shown in Fig. 233.

in the operation of it may be said to act as a single effect. This is evident from the circumstance that the whole of the vapour generated in the kettle is artificially condensed by

the action of cold water circulating in the refrigerator tank, the heated overflow water from which runs to waste. It is not, moreover, altogether safe, owing to the volatile nature of the fermented wash and the consequent danger of premature dispersal of the spirit, to attempt to heat the latter on its way to the still by means of such overflow, or by any immediate application of the vapour, unless the most stringent precautions are taken, the resultant complications connected with such safeguards virtually rendering attempts of this nature of doubtful advantage. When, however, the use of retorts is introduced, as seen in Figs. 232 and 233, an increased effect is immediately obtained. But to promote a definite and considerable economy of fuel, on sound lines, combined with continuous in place of intermittent working of such apparatus, continuous stills of various kinds have been designed and employed, and their use has approximately reduced the above-mentioned coal account from 10 cwts. to some 6 cwts. per 105 gallons of rum produced.

One of the best known and most original forms of continuous apparatus is found in the Coffey Still, as seen in Figs. 235 and 236. This still consists of two separate columns of considerable height, built up in a series of rectangular wooden frames resting one upon another, each series being jointed together and kept firmly in position by a sufficient number of vertical tie rods. The longer column to the right hand is known as the analyser, which may be said primarily to take the place of the large kettle of the pot-still. The second or left-hand column is known as the rectifier, and this supplants the retorts and rectifiers of the earlier form of apparatus. Coffey Stills are also frequently constructed with copper frames, and Fig. 237 shows a plan and elevation of a still of this description. Here A is the analyser; B, the rectifier; C, the overhead

vapour and feints condenser; D, the spirits refrigerator; E, the hot feints receiver; F, the wash pump; G, the water pump; H, the spirit test case; K, the reducing valve; L, the

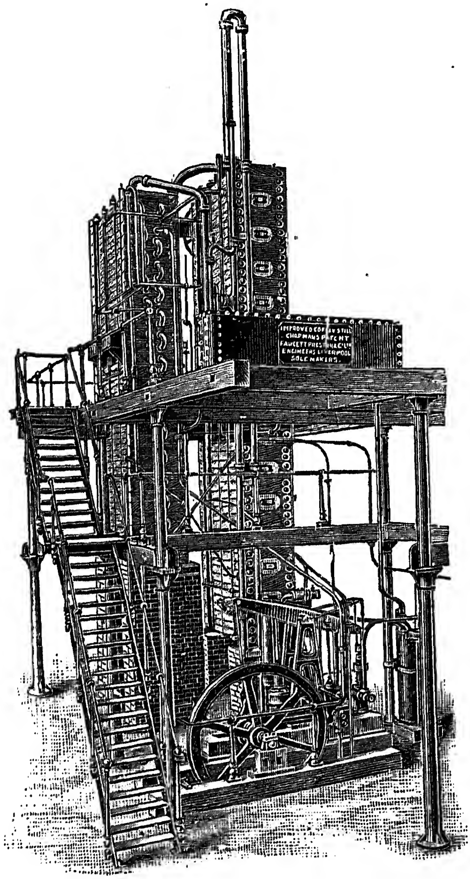


FIG. 235.—General view of a complete Coffey Still, built with wood frames, with its immediate accessories.

steam stop valve controlling the steam-supply; and M, the cold feints receiver. The details of construction, manipulation, and control of this apparatus are exactly the same as those adopted in the case of the still made with wooden

frames, and this particular illustration demonstrates the construction and working of Coffey Stills, whether made

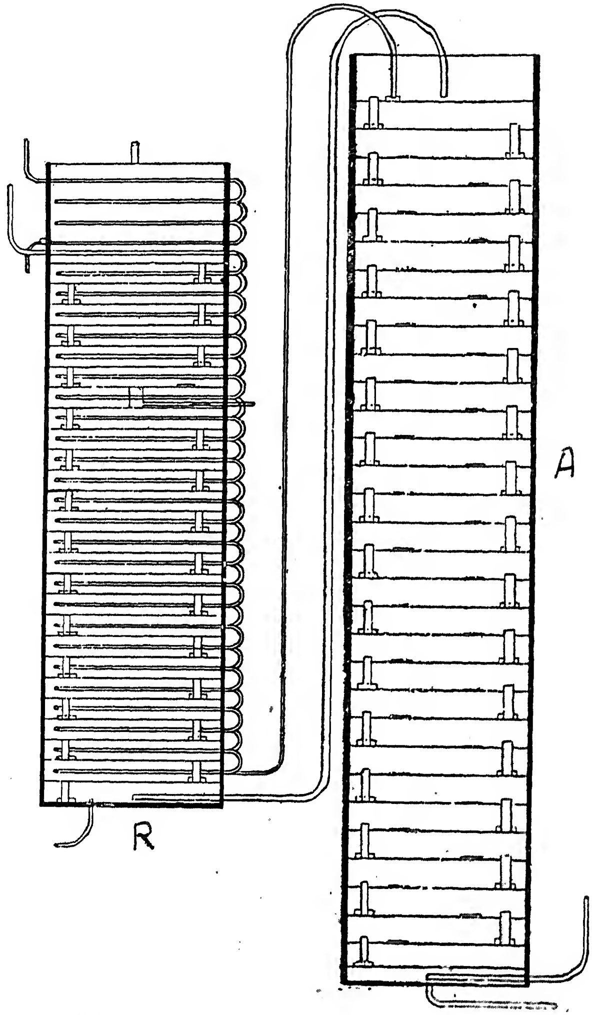


FIG. 236.—Sectional diagram, in elevation, of the analyser and rectifier of a Coffey Still.

in wood or copper. Both the analyser and rectifier columns are divided into numerous shallow chambers by the inter-

position of copper plates fixed between the consecutive compartments. In the case of the analyser, these plates are perforated throughout with numerous holes of small diameter. They are each of them also fitted with a disc-valve, a vapour-sealing cup, and a dip pipe. The latter projects about an inch above each diaphragm, and some seven or eight inches below it, and dips into the vapour-sealing cup of the next lowest plate. (See Fig. 236.) These arrangements ensure the maintenance of a sufficiently thick film of wash over the entire surface of each diaphragm, and in case the rising vapour is unable to force its way with sufficient velocity through the perforations and the super-imposed wash, it can obtain a passage through the disc-valves. The diaphragms of the rectifier are for the most part of a similar character, and are fitted like those of the analyser, save that a certain number of the diaphragms in the upper chambers have no valves or perforations, and these divisions are separated from the lower chambers by unperforated copper sheets. This modification causes the alcoholic vapour throughout the final stages of its upward passage amongst the coolest surfaces of the wash pipe to proceed in a serpentine course, via large openings in the alternate ends of the consecutive and unperforated plates.

The analyser and rectifier are connected together; first, by a large vapour pipe, which may be described as passing from the top of the analyser to the bottom of the rectifier; secondly, by a small wash pipe which passes in a reverse direction, that is to say, from the bottom of the rectifier to the top of the analyser. This wash pipe is a continuous and impervious connection throughout its entire downward course from top to bottom of the rectifier, and winds in repeated alternate directions throughout the chamber space of each frame, likewise bending out and in again from one division to another, as seen in Figs. 236 and 237. It is

through the regulating valve at the upper end of this pipe that the fermented wash is first introduced for treatment in the still. This cold liquid, therefore, follows the serpentine course of the pipe throughout the rectifier, and, acting through the medium of the pipe walls, partially condenses the rising vapours which pervade the chamber spaces, and is itself heated. Proceeding through the pipe continuation, from the bottom of the rectifier to the top of the analyser, the heated wash is discharged over the entire surface of the top diaphragm of the latter, and flows down this column from tray to tray, in a zigzag direction, passing down the dip pipes, which are placed, as shown and already explained, at alternate ends of the plates. Ultimately reaching the bottom of the analyser, in the form of "spent" wash, it leaves the still via the right-hand bottom syphon pipe and runs to waste.

While this movement of the wash has been in progress, a reverse series of operations has simultaneously been established. Steam, at a suitable pressure, has been admitted into the bottom of the analyser, through the steam-admission and reducing valves, seen in Fig. 237. It passes upwards through the perforations in the successive plates, and through the inch-thick layers of wash maintained on the upper surface of each diaphragm by the projecting upper end of the dip pipe already described. The cups in which the lower ends of the dip pipe stand are always full of wash, and thus act as a seal, confining the passage of vapour to these perforations and the disc-valves. The steam in its passage through the wash deprives it of its contained alcohol as indicated above, and a mixed vapour of alcohol, water, and other volatile constituents leaves the analyser via the large vapour pipe, and is led into the bottom of the rectifier. Here, as this vapour comes into contact with the cool surfaces of the continuous wash pipe,

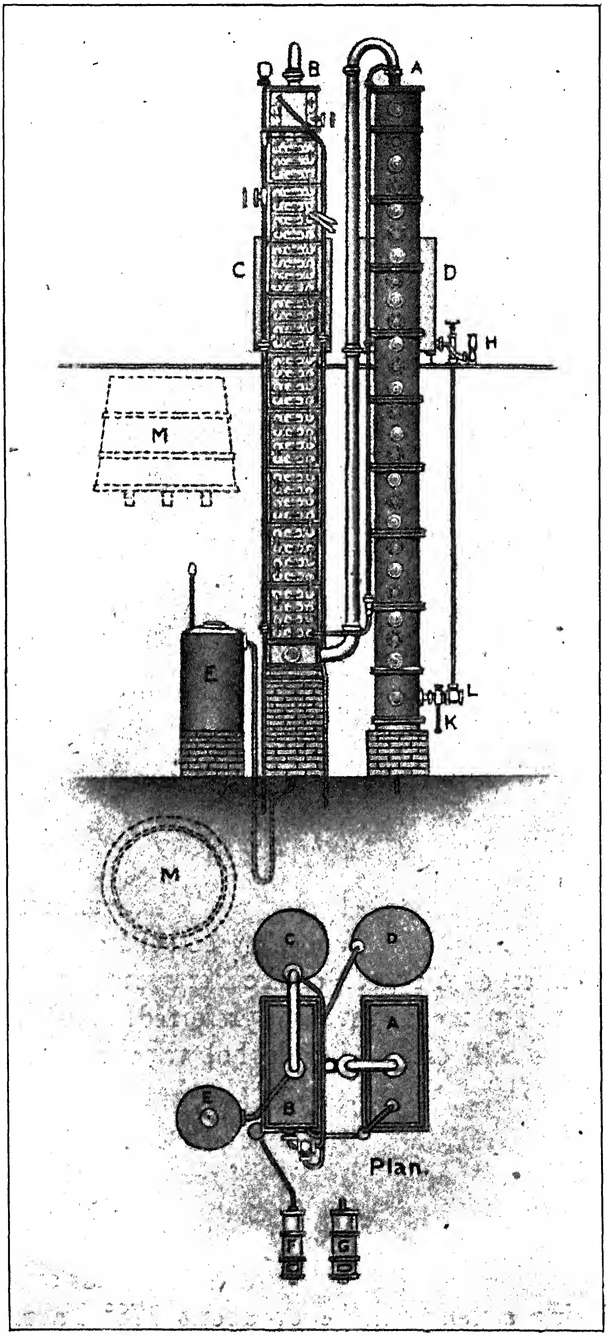


FIG. 237.—Plan and front elevation of a Coffey Still, built with copper frames, showing its various fittings and accessories.

already described, it is partially condensed, at the same time heating the wash; and at this stage the water vapour and other bodies of a high boiling-point, as well as some alcohol, condensed, are continually withdrawn through the "hot feints" syphon attached to the bottom of the rectifier. The alcohol, for the most part, condenses in the upper chambers of this column, and, falling down on to the "spirit plates," is received and conveyed by a special pipe to the refrigerator, and thence to the spirit store. A pipe leading from the top of the rectifier takes away any remaining and uncondensed vapour, which also passes through another refrigerator, and forms the "cold feints," both the hot and cold feints being subsequently mixed with the succeeding wash for re-distillation. The proportions of the still are so calculated that, in conjunction with a proper regulation of the steam and wash supplies, the temperature of the wash when it leaves the rectifier will usually stand at from 190° to 200° Fahr., and as it subsequently falls through the analyser it is, as already mentioned, completely exhausted of all spirit. So, too, the vapour passing over from the analyser to the rectifier will stand at a temperature of about 210° Fahr.

This form of still should be worked as uniformly and continuously as possible, and may be controlled either by the regulation of the wash or the steam-supply, the latter method being more usually preferred. An excessive temperature will cause the alcohol vapour to escape in undue quantities through the cold feints pipe, simultaneously retarding the condensation of watery vapour, with a resultant weak spirit, while a low temperature permits too much alcohol to condense below the spirit plate, thus increasing the quantity of hot feints. In the manufacture of rum these undesirable alternatives are best avoided by maintaining a temperature of about 178° Fahr. in the

vapour space of the second or third sections above the spirit plate, corresponding to a spirit strength as rum of 48° to 50° O.P. The strength of the spirit escaping from the still at any moment is ascertained by the use of the customary glass bubbles, which rise or fall as the spirit becomes weak or strong; and, as a further guide, thermometers are fixed in communication with the interior of various sections of the still. Various points of a more technical nature need not here be noticed; but it will be perceived that the hot vapour from the boiling wash has been used to heat the incoming cold wash, instead of its heat being wasted as in the case of the simpler forms of pot-still; and that by the above arrangements a considerable economy of steam, and therefore of fuel, has been effected, as noted at the beginning of this description of a continuous still. This apparatus is not only economical of fuel, but also of water, and it will continuously produce a strong spirit, coupled with a complete exhaustion of the wash.

Fig. 238 shows another form of continuous still of modern design. It consists of one column, comprising the large still-kettle A, upon which stands the analysing and rectifying column B. This is supplemented by the two rectifying wash heaters C and D, which, as their designation implies, not only promote the rectification of the spirit, but likewise heat the wash as it passes successively through the tubes of these vessels on its way to the column B. It will likewise be noticed that the finished spirit is finally condensed in the refrigerator or condenser E. The cold and fermented wash is elevated to the overhead wash tank by the pump seen in the illustration, whence it runs into the first wash heater D. Here it receives a certain amount of heat from the alcoholic vapours passing through the body of the heater. It next passes into the second vessel C, in

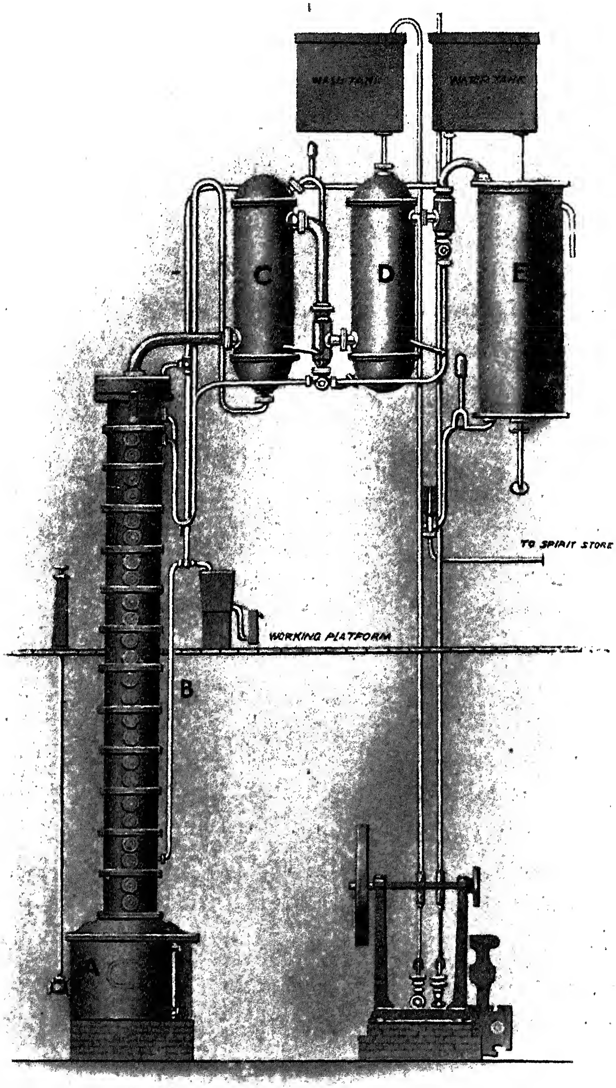
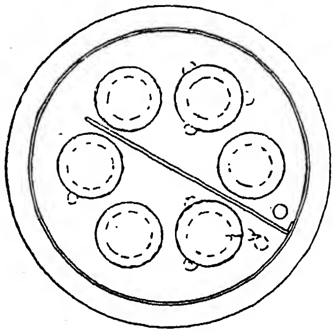


Fig. 238.—Front elevation of a special form of patent continuous steam still, with large still-kettle, or steam-chamber, surmounted by a distilling and rectifying column, and fitted with rectifying wash-heaters and spirit separators.

which a further degree of temperature is reached, the behaviour of both the wash and vapour in C being precisely similar to that described in connection with D. The wash now proceeds to the rectifier and analyser column B, and is delivered on to the upper surface of the top diaphragm of this column. Fig. 239 gives a sectional plan and elevation of the latter, from which it will be seen that the wash, through the action of a central, shallow, vertical division plate in each chamber, is made to travel in a double direction over the entire surface of each diaphragm at a stream depth of about an inch of liquid, such depth being maintained by a corresponding projection of each dip pipe above the upper surface of each plate. During such passage it is acted upon by the ascending vapour, which rises from the next lowest compartment into the small steam domes attached to the upper side of each diaphragm, and escapes, through the wash, around the lower circumferential edge of each dome. The wash



PLAN OF PLATES

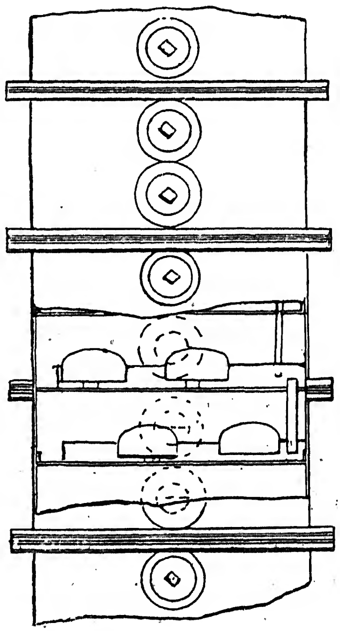


Fig. 239.—Sectional plan and elevation of the distilling and rectifying column shown in the previous illustration.

descends stage by stage through the numerous and successive chambers of the column till it is entirely exhausted of spirit. While this downward movement of the descending fluids proceeds, an upward vapour current is established by the admission of steam into the body of the kettle A (Fig. 238), which receives the "spent" wash. This rising vapour passes through the successive chambers of the column, depriving the descending wash of its contained alcohol, and the vapour of alcohol, water, and other volatile constituents leaves the top of the column and passes through C and D, the hot feints from these vessels being returned direct to the still column through specially arranged connections. Finally, the spirit is condensed in the refrigerator E, and a good quality of rum is obtained, free from impurities, and still retaining its aroma and flavour.

Rum as it comes from the still consists of alcohol, together with the following bodies in varying proportions:—

Aldehyde.	Furfurol.
Acetic ether.	Amylic and higher alcohols. } Fusel oil.
Butyric ether.	
Propionic ether.	Water.

Of these, the distinctive flavour of rum is due to acetic, butyric, and propionic ether, especially the butyric. Acetic ether has not much flavour in itself, but forms frequently as much as 95 per cent. of the ether contents of the rum. In high-class rums the intense pine-apple flavour of butyric ether is distinctly noticeable, although but a small proportion of this flavouring matter is generally present. Aldehyde helps to give the hot flavour to new rum. This disappears as the aldehyde is gradually oxidised or "aged" into acetic acid, some of which ultimately

becomes acetic ether. Fusel oil should not exist to any marked extent in rum.

Given a wash of a certain ether content, the proportion of ethers which appear in the rum will depend a good deal upon the strength at which the rum is "run." If this be too high, the spirit will be wanting in flavour owing to some of the flavouring ethers being left behind. If it be too low, there is danger of fusel oil and products of relatively high boiling-point being introduced in objectionable amount. Care is, therefore, taken to run the spirit at a maximum strength compatible with the maintenance of flavour. With pot-stills, as stills of the "kettle" type are called, this desirable result is obtained by invariably "cutting" the rum when it falls to a certain strength. To this end small glass balloons, called bubbles, are employed. These are so weighted that they float in spirit of a certain density and under, sinking when the strength rises to a higher point. A sampling arrangement consists of a glass cup, so arranged that a small pipe connected with the discharge of the condensing worm supplies a slow but continuous stream of the spirit to it. Directly the rising of the particular bubble denotes that the strength of the spirit has sunk to the "cutting" point, the flow of spirit is diverted into the second receiver.

With continuous Coffey Stills, the steam and wash supplies having been roughly adjusted, the flow of spirit at constant strength can easily be secured by the use of a thalpotassimeter, or thermometer in which the indications are obtained by means of the expansion of ether vapour operating on the needle of a dial, placed in the second section of the rectifier above the spirit plate. The temperature corresponding to the desired strength of outflow being ascertained, the slightest opening or shutting of the spirit valve regulating the outflow will give the necessary fine

adjustment. A suitable strength for continuous-still rum is 48° O.P.

Rum as it comes from the still is colourless, and requires to be coloured before it is fit for the potable market. The colour which is used is made by converting the sucrose of the sugar or molasses into caramels by burning. This is usually done by placing the sugar or molasses to be burnt in a "copper," one of the iron tayches at one time used for open evaporation, together with sufficient water to allow of its being thoroughly mixed in the process. Fire is then applied, and the contents of the copper heated to the desired point. If a high degree of colour is desired, the burning has to be carried on to a degree just short of charring, determined by the behaviour of a drop of the burnt colour when dropped into water. The ultimate point of a less highly burnt colour is decided by the length to which a small sample, a "string," can be drawn out without breaking. In either case the desired point having been obtained, the fire under the copper is quickly withdrawn and its contents cooled with water. These are then transferred to the rum store and mixed with spirit, the mixture being allowed to stand for some days to permit of any separated solid matter settling. The colour thus made, in the quantity necessary to give the requisite tint, is added to the uncoloured rum in the rum butts, and after standing for some days to settle, the clear coloured rum is drawn off.

The rum thus treated, which for practical purposes consisted, before colouring, of water and alcohol, now contains solid matter in solution, the caramels formed by the burning of the sugar. The strength of the rum can therefore no longer be determined with accuracy by the hydrometer. Before the colour was added, the specific gravity gave a close indication of the percentage of spirit present. As a solid substance has now been added, heavier than

water as alcohol is lighter, the use of the specific gravity bottle or hydrometer will indicate a lower percentage of alcohol than the actual, in proportion to the amount of the solid matter added in the form of colour. In other words some of the alcohol has been "obscured" by the colour, and the proportion of alcohol so obscured is termed the "obscuration" of the spirit. This is either expressed, as by the Customs in this country, in terms of the degree of proof obscured, or in terms of the percentage of proof spirit obscured. Thus, if a spirit of 44° O.P. becomes 42° O.P. by the hydrometer when coloured, the obscuration would be either 2° as expressed by the English Customs authorities, or $\frac{2 \times 100}{144} = 1{\cdot}38$ per cent. expressed in terms of proof spirit. Spirit of 44° O.P. contains alcohol equivalent to 144 per cent. of proof spirit, proof spirit being determined as being composed of 57·0 per cent. absolute alcohol and 43·0 per cent. water by volume at 60° Fahr. When rums require to be heavily coloured and at the same time to have a less limit of obscuration, the colour has to be burnt to a high degree. Care, however, has to be taken that this has not been carried too far, as otherwise higher caramels are produced which cause "faultiness" or a turbid condition of the rum when the latter is "broken down" or mixed with water.

A frequent flaw in strong rums from a buyer's point of view is what is known in the trade as "faults." These consist in the production of a turbid appearance, on standing, when water in the proportion of about two parts of water to one of rum is added. This turbidity is produced by any of the following causes:—

1. Over-burnt colour.
2. Extraction of resins from the casks.
3. Presence of an undue amount of lower products from the low wines.
4. Hard water.

In recent times the question of the production of alcohol from molasses for the manufacture of motor spirit to take the place of petrol has attracted considerable attention. For this the fermentation should be conducted in the manner set forth earlier in these pages for the manufacture of Demerara rum. But, unlike rum, alcohol for these purposes has to be distilled at a very high strength, 66° over proof—equivalent to 95 per cent. by volume of pure alcohol—being required. A continuous still, especially designed to deliver spirit of this strength, has to be employed, and it is also important that it should produce spirit as "silent" as possible, being directly opposite in this respect to a still for rum manufacture.

Fig. 239A shows a still well calculated to satisfy these requirements. It consists of a number of circular sections containing the concentrating plates. The ascending steam which enters at the lowest section of the boiling column passes through a number of circular holes in the plates, over which are mounted inverted cups or "bells," which are arranged so that the steam is distributed evenly in a fine spray through the liquid, which, entering at the top of the boiling column, descends and is collected on each concentrating tray. A tubular overflow is provided for the liquor in each section, the upper edge being arranged to ensure the correct mixing and flow of the steam and liquid. The overflow is carried down into the next section and sealed by the liquid to prevent any steam rising through the column without passing through the liquid.

In order to obtain the maximum heat economy a preheater is supplied, arranged so that the incoming liquor is raised in temperature by means of the exhausted hot wash from the boiling column, which arrangement effects considerable economy in the steam consumption. A steam regulator operating on a float principle is also supplied,

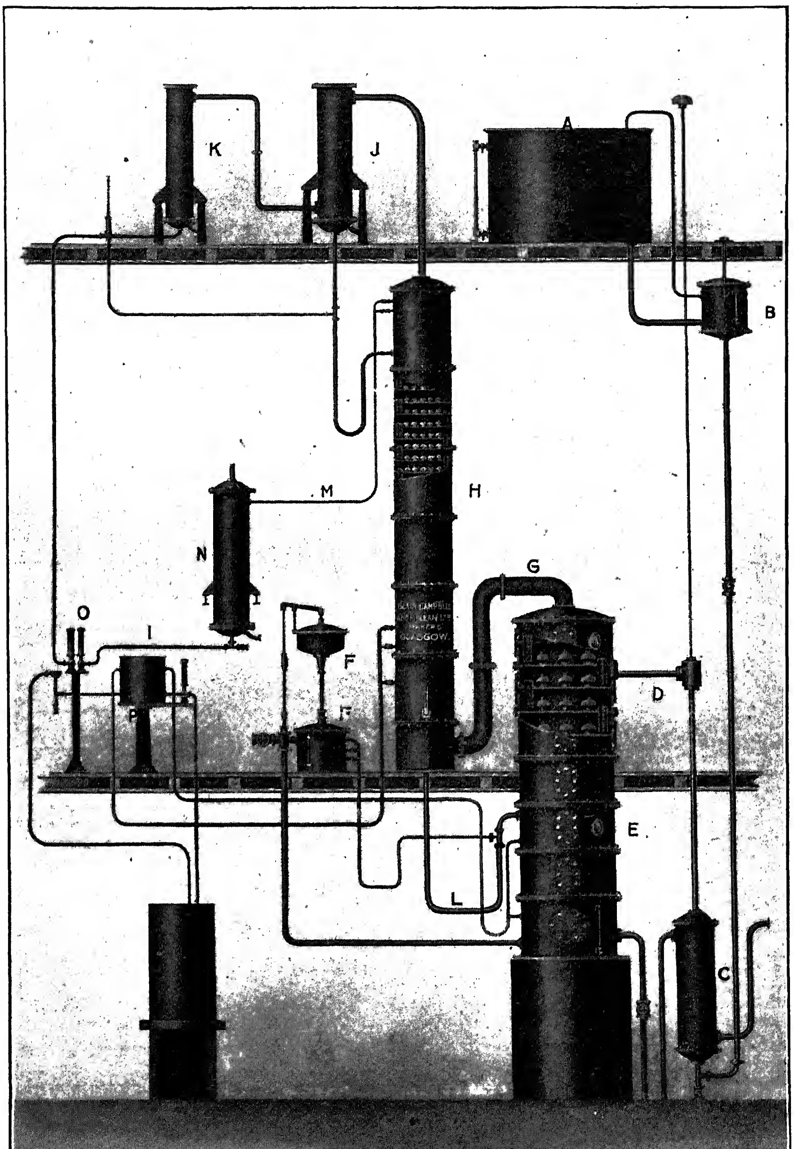


FIG. 239A.—Double-column continuous still for the manufacture of commercial alcohol from cane-sugar products.

and this, together with a liquor-controlling device, ensures a steady and constant supply of steam and liquor, thus rendering the plant practically automatic in operation, and calling for a minimum of attention and labour.

In working the still, the fermented wash is taken to supply tank A, where it runs by gravity through the float regulating tank B, which maintains, by means of a regulating device, a constant head and a regular flow of wash to the still. It is then fed into the preheater C, where it is heated by means of the exhausted hot waste liquor, and is then carried on through pipe D into the top portion of the boiling column E, where it flows down from plate to plate until it passes out as waste liquor at the foot of the column and into the preheater.

The steam is admitted into the boiling column E by means of the automatic steam regulator F. The steam vapours rise through the descending flask and remove the alcohol in the form of vapour, which passes out at the top of the boiling column E through the vapour pipe G into the foot of the rectifying column H. The alcohol-bearing vapour is further concentrated in the rectifying column H, and is purified by having to pass through the returning pure alcohol, which is condensed in the overhead rectifier J and condenser K. The impure alcohol which collects on the plates in the rectifying column H is returned to the boiling column E through pipe L to be redistilled. The purified alcohol at the required strength passes over from the top of the rectifying column H through pipe M into the cooler N, and is drawn off through observation glass O and run to receiver. The alcohol flow at this point is in view all the time, and is tested at this point by hydrometers.

The lighter vapours are run off from condenser K through a separating tester, whence a portion is returned

to the top of the rectifying column; the remainder being passed through an observation glass, tested, and run to a receiving tank.

The heavier fusel oils are collected in the condensing tank P and are then run to a receiving vat, where they separate out and are drawn off and returned to the boiling column with the wash.

The scientific control of the distillery is conducted on very similar lines to that of the sugar factory, save that the microscope plays an important part in the supervision. The sugar, represented by the rum made, is put against the quantity of sugar entering the distillery. While, however, in the case of the sugar manufacture the balance-sheet is drawn up in terms of crystallisable sugar, in the case of the distillery the glucose, or uncrystallisable sugar, forms an important item in the accounts, the spirit being produced from it just as much as from cane sugar—in fact, the latter has to be converted into uncrystallisable sugar before it is ready for the splitting up process, engendered by the yeast plant, which results in alcohol. It is therefore convenient to express the whole of the sugar going to the distillery, in the form of molasses and washings, as uncrystallisable sugar. This is done by adding $\frac{1}{20}$th to the amount of cane sugar, and the debit side of the account will be made up of cane sugar + $\frac{1}{20}$th + uncrystallisable sugar. The credit side will consist of the sugar, again expressed as uncrystallisable sugar, equivalent to the spirit produced. One gallon of proof spirit at a temperature of 84° Fahr. is equivalent to 8·7 lbs. of glucose or uncrystallisable sugar, and the amount of the latter corresponding to the rum made is thus readily obtainable. The sources of loss are in fermentation, in the bottoms of the vats which do not go to the still, and in the actual distillation. When the rum is coloured an apparent loss of spirit occurs by virtue of the

obscuration, the nature of which has been already explained.

The balance-sheet of the distillery will, therefore, be as follows:—

Dr.		Cr.	
Sugar, dealt with as glucose		Glucose, equivalent to spirit made	
		Lost in fermentation ..	
		,, bottoms	
		,, distillation	
		Unaccounted for	

The loss in fermentation is found approximately by utilising what is known as the attenuation of the wash, *i.e.* the number of degrees of specific gravity which the wash has lost during the process of fermentation. Thus, if the original specific gravity of the wash when set up is 1·062, and the specific gravity of the fermented wash, taken at the same temperature, is 1·010, the attenuation would be $62° - 10° = 52°$. As this lowering of gravity is the direct result of the production of alcohol, the extent of it is a direct measure of the quantity of alcohol produced, subject to some slight variation according to the amount of ethers formed during the process. With the fermentations which obtain in rum, 1·06 gallons of proof spirit per five degrees of attenuation per 100 gallons wash is a fair figure to take. The above attenuation would, therefore, indicate $\frac{52 \times 1{\cdot}06}{5} =$ 11·024 gallons of proof spirit which can be expressed as uncrystallisable sugar, and the amount of this compared with the quantity in the wash set up. A more accurate manner, when opportunity affords, is actually to estimate the quantity of alcohol formed in each vat of wash by distillation in a laboratory still. The quantity of spirit

going to the still in the form of wash being thus known, comparison with the amount yielded gives the loss due to the still.

In addition to the above records, frequent microscopic examinations of the wash are made, and putrefactive bacteria of all descriptions looked for. It is out of the question to obtain wash quite free from these unwelcome visitors, but whenever their presence assumes aggressive proportions the entire wash-loft and accessories require cleansing.

In no part of a cane-sugar factory is there so much pleasing scope for the chemist as in the distillery. Constant source is afforded of investigation, not only on the development of the yeast plant itself, but also in the study of the action of the bacilli which develop the important characteristic flavours of rum. In fact, a distillery of any magnitude should have a chemist's whole time devoted to it. The problems which occur in the manufacture of rum are many, and can only be thoroughly grappled with by constant scientific attention.

The great importance of the manufacture of rum, which has just been described, cannot well be overestimated in its relationship to the general economy of most sugar estates. Nevertheless, the considerable fluctuations of the rum market, and the necessity for limiting production, coupled with the undesirability of trusting entirely to the uncertainties of a single outlet, render the possibility of the utilisation of molasses in other ways an acceptable opening worthy of the consideration of sugar-planters.

In tropical countries it is a well-known fact that cattle greedily devour cane-sugar molasses. Its great value as a food accompaniment has thus long been recognised, and it may even be termed a condimentary food. It is not to be altogether regarded as a complete food in itself, but is an

excellent substance to mix in greater or lesser quantities with other nutriment. Not only is it rich in nutritive and force-giving material, but its excellent flavour conduces largely to its appreciative consumption by animals. It is free from the excessive saline matters which beet-sugar molasses contains, and from the objectionable smell and flavour of the latter. Cattle improve in appearance and fatten enormously on it, by reason of the large amount of carbohydrates—sugar—which it contains, and the same cause leads it to be particularly suitable for use where great muscular work is required.

Cane-sugar molasses would long ago have been more largely used for cattle-feeding, in cold and temperate climates, were it not for the expensive and inconvenient packages indispensable for its shipment and distribution, a watertight receptacle being necessary for its conveyance in its natural condition. Efforts have therefore been made from time to time to use various substances as absorbents, so that the molasses can be economically and conveniently shipped, and readily handled in a comparatively simple manner. While the use of the beet-sugar molasses has developed in the manufacture of a similar product in which the absorbent agent is peat-moss, and of compound feeding-cakes and special mixtures, sugar-cane molasses has also been combined with the inner part or pith of the sugar cane, with a rice produce or débris resulting from the milling of the paddy or crude rice grain, and with tapioca refuse.

The first of the above absorptive agents is the cellular portion of the cane itself, formed of a number of minute cells, obtained from the coarse megass by disintegration and screening. The major portion of this substance is a digestible food in itself. It is likewise a powerful absorbent, and possesses the property of imbibing four times its own weight of molasses. This fact, however, is not altogether

surprising, when it is remembered that the cells of which this honey-combed ingredient is chiefly formed originally held between seven and eight times their weight of juice. The original juice is in reality, in this manufacture, replaced in these cells by molasses; and a sufficiently dry meal known as "Molascuit" is thus obtained, which can be conveniently shipped in good condition. The following statement may be taken as a fairly approximate analysis of its composition:—

Sugars	57·62
Digestible cellulose, etc.	13·22
Indigestible fibre	5·91
Albuminoids and nitrogen	2·31
Oil	0·23
Ash	6·71
Moisture	14·00
	100·00

The method of manufacture is comparatively simple. The finer portions of the megass are collected either by sifting through suitable screens, by utilising the considerable quantities of fine megass which fall through the megass carriers, or by passing the coarser megass through a shredder or disintegrator. This fine megass usually contains somewhere about 50 per cent. of water, and requires to be thoroughly dried by steam or fire-heat, after collection, before its full value as an absorbent can be obtained. If disintegrators are employed on the coarse megass, the latter must be dried before treatment in the machines; when the finer stuff is simply collected from the carriers and by sifting, it is freed from moisture immediately before it is mixed with the molasses.

Figs. 240 and 241 show a very complete plant which is used for the manufacture of Molascuit meal from the coarser megass. In the employment of this machinery, the megass

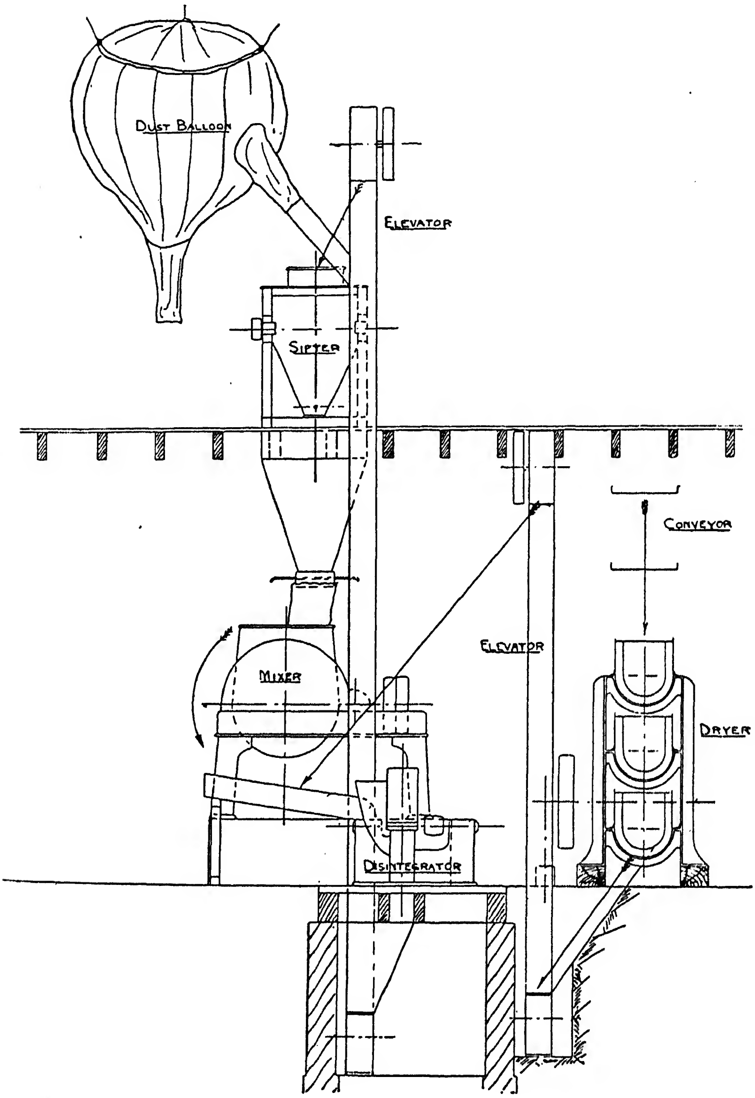


FIG. 240.—Elevation of a complete Molascuit plant, in connection with which disintegrators are used.

is first brought by a suitable conveyer to the steam drier, whence it next proceeds to the disintegrator. After disintegration it is raised to the sifter by means of the elevator

seen in the plans, and from the sifter the sorted megass dust gravitates to the mixer, in which it is amalgamated with the proper proportion of molasses. The latter, as it comes from the centrifugals, usually standing at a density of from

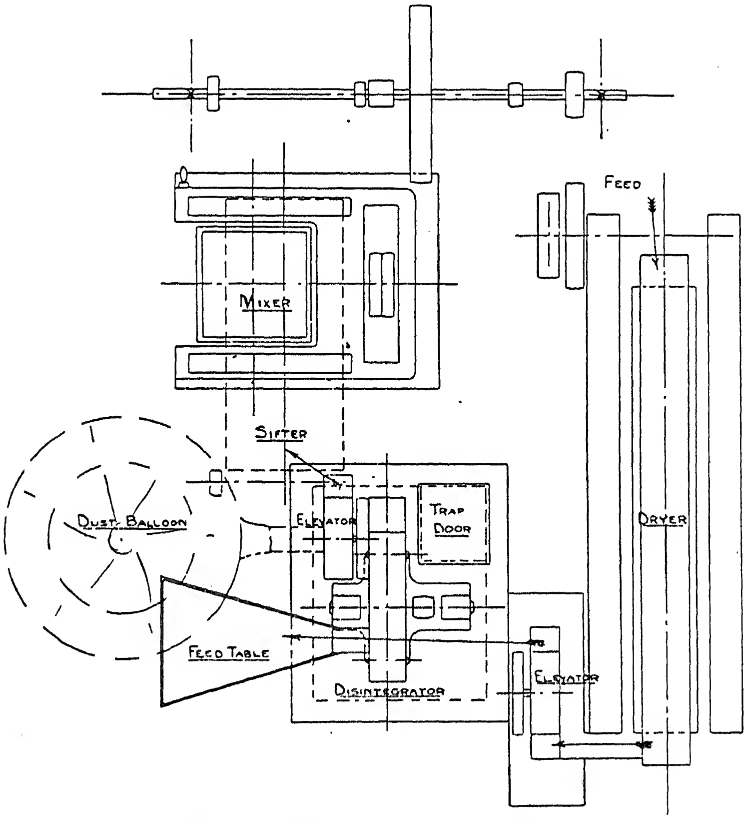


Fig. 241.—Plan of the Molascuit installation shown in Fig. 240.

38° to 40° Bé., is too thin for satisfactory work. It requires, therefore, to be further concentrated before it is in a suitable condition for this particular use. Such concentration is effected in the vacuum pan, a density of about 48° Bé. being usually sought. The molasses and megass, having been prepared as above, are thoroughly mixed, as

already mentioned, in the proportion of about 80 parts of molasses to 20 of megass; and it is a great advantage, with a view to securing satisfactory results, if both ingredients are as hot as is conveniently possible when mixed. This viscous mixture is now laid out to cool and dry, and the resultant sugary granular meal, thus obtained, is subsequently packed in bags for shipment.

On estates where multiple crushing is the practice, disintegrators are not usually employed, the large quantities of megass dust, which fall from the carriers, as already mentioned, being relied upon as a sufficient supply. Fig. 242 shows another form of drier which can then be used with advantage. In its case heat is preferably supplied by the waste gases from the boiler furnace; again, the apparatus may be set with a small and independent fire-grate of its own, or be fitted with a steam-casing. It will also deal with the coarser megass on its way to the disintegrators when such machines are employed. The apparatus consists of a revolving drum fitted with a series of internal circumferential compartments placed within a brick chamber. The waste gases are led into this chamber, and heat the drum. As the latter revolves, the fine megass continuously falls in cascades from the top to the bottom; and, under the influence of the applied heat, gives up its contained moisture. Whilst the process of drying is in progress, the megass can be readily examined at any moment; and when dry can be promptly and automatically removed by means of an adjustable deflector, which is an integral part of the machine. Once the latter is started it works continuously, and need not be stopped either for the purpose of charging or discharging its load.

Another form of molasses cattle-food—"Colco"—already referred to, is also manufactured. In its case the absorbent is the débris resulting from the milling of the

"paddy," or crude rice grain. This is not specially dried or disintegrated, as in the case of megass, before being mixed with the molasses. At the same time it does not absorb

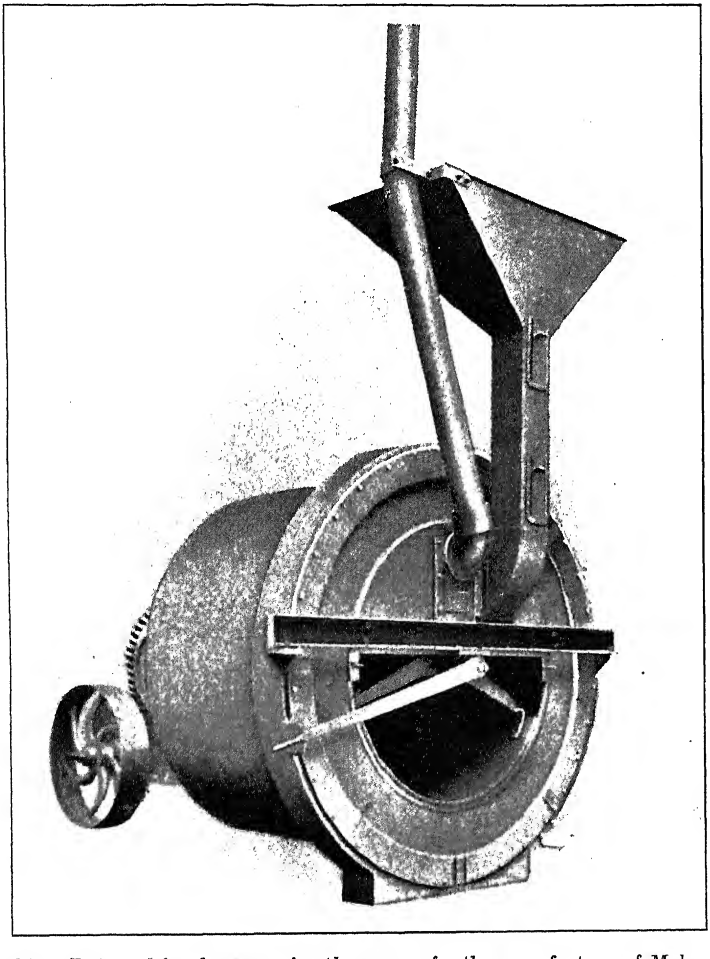


FIG. 242.—Rotary drier, for preparing the megass for the manufacture of Molascuit.

so much molasses as megass, not more than 60 parts being present per 100 of the finished product; but on the other hand it contains nutritive bodies belonging to the raw

product used. The general practice of the manufacture of this cattle-food, though of a modified and simpler character, is not altogether dissimilar from that of Molascuit. It has in view the same provision of a condimentary food for animals, which can be conveniently shipped and distributed, and it is unnecessary to enter into precise details of the manner of its production. The following figures furnish an approximate analysis of the composition of Colco:—

Moisture	12·43
Oil	1·75
Albuminoids	3·86
Carbohydrates	57·38
Fibre	12·84
Ash	11·74
	100·00

In Java, in addition to that of rice and coco-nut, tapioca refuse is mixed with the molasses, and a similar form of cattle-food is thus obtained. By means of each one of the above processes, the molasses is embodied in such a form as enables it to be shipped profitably and with ease. This highly valuable food product is thus brought to the doors of the home farmers, stock-breeders, and horse-owners in a most convenient form for distribution and use, at a comparatively moderate cost. The value of such commodities in cold and temperate climates, during the winter months when fodder is scarce, cannot be overestimated.

Another possible by-product, which has attracted some attention from time to time, is paper manufactured from megass. Although it has been proved that paper of good quality can thus be made, it has yet to be shown that it can be done so generally at a profit. In any case such manufacture must necessarily be confined to those localities where there is an abundant supply of good and pure water, with fuel which could take the place of the megass.

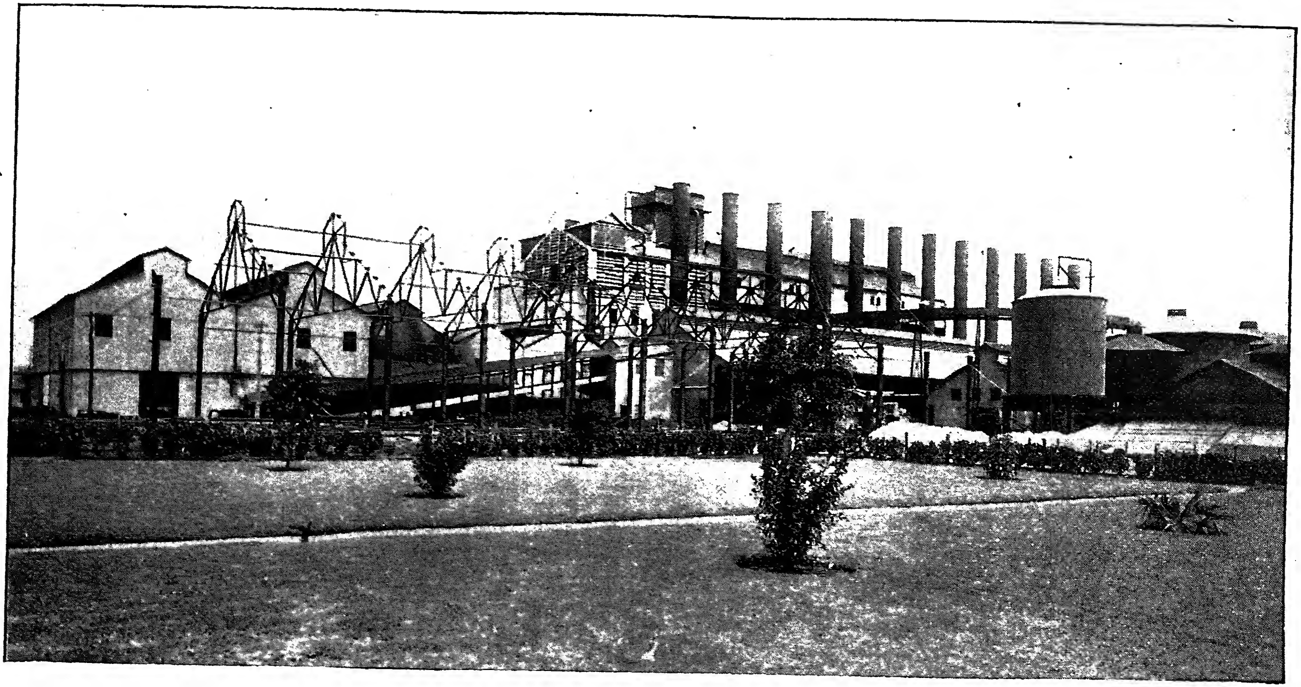


FIG. 243.—A cane sugar factory in Cuba.

Another of the by-products of the manufacture of sugar from the sugar cane is wax. This is contained in the rind of the cane and is accountable for the "bloom" which characterises the appearance of some varieties. In the course of the milling, a large proportion finds its way into the juice, where it remains in suspension until carried down by the impurities separated in clarification, ultimately finding its way into the filter press cake, which contains from 10 per cent. to 16 per cent. of the crude wax.

The recovery of the wax is not carried out commercially to any extent, but several processes have been advanced for the purpose. In the few instances, however, in which it is done, the filter cake is dried and powdered. It is then extracted with hot benzene, and the extract filtered from the residue. The benzene is then either distilled off from the wax, or the hot extract is allowed to cool, when the greater part of the wax is deposited and separated by filtration. In either case the benzene is again used for extraction.

The crude wax thus obtained contains from 30 per cent. to 50 per cent. of pure wax, which resembles the wax recovered from the Carnauba palm. It is sold in the crude state to wax refiners.

Potash, recovered either from the molasses or from the lees of the distillery, also forms a by-product which is attracting the attention of cane sugar producers.

This account of the manufacture of cane sugar and its by-products is now complete. An endeavour has been made to write it in a way which will, it is hoped, render it particularly serviceable to those who are not possessed of special technical training; but who, nevertheless, are desirous of ascertaining particulars of the machinery and processes used, with which they are brought into actual contact, or in which they are directly or indirectly interested.

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